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Desiree L. Lawson

AN ANALYSIS OF VEGETATION AND ENVIRONMENTAL PARAMETERS AT MITIGATED WETLAND SITES LOCATED IN THE UPPER SCIOTO RIVER DRAINAGE BASIN, CENTRAL OHIO

By

Desiree L. Lawson

Department of Biological Sciences
Marshall University

Dan K. Evans, Ph.D., Committee Chairperson
Frank S. Gilliam, Ph.D.
Jeffrey D. May, Ph.D.

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ABSTRACT

An Analysis of Vegetation and Environmental Parameters
at Mitigated Wetland Sites Located in the
Upper Scioto River Drainage Basin, Central Ohio

Desiree Lynn Lawson

The construction of wetland mitigation sites to compensate for authorized losses is necessary under Section 404 of the Clean Water Act. Many mitigation sites have been determined to be unsuccessful. Monitoring of sites is necessary to determine if functions of natural wetlands have been replaced. Six mitigation sites in the Upper Scioto River watershed in central Ohio were chosen for study. Representative transects were established beginning in uplands adjacent to the wetlands (old field, OF), running through areas characterized by seasonal inundation (seasonally pooled, SP) and ending in permanent pools of inundation characterized by little or no vegetation (permanent pooled wetland – PW). Transects ranged between 60 and 110 meters, with between three and five per site. Vegetation was sampled by placing 1-meter square quadrats every 10 m along transects. Vegetation was identified and percent cover and frequency were collected to determine importance values. Soils were sampled to a depth of 10 cm along each transect and in each zone of OF, SP and PW. Extractable NO_3^- and NH_4^+ were determined before and after laboratory incubation to determine net nitrification and mineralization. Vegetation sampling determined a total of 121 species were present in the herbaceous layer of the wetlands, 37 of which were non-native. Of non-native species, eight are recognized as invasive. Aerial cover was at least 100 percent in most quadrats. Of the 15 dominant species at each site, all but one site contained between one and four non-hydropytic species (i.e. FACU or UPL/NI). In most sites, OF zones were dominated by upland species and SP and PW zones were dominated by hydrophytic species. Species from 12 genera present in study sites are recognized as valuable to wildlife as food sources. Calculation of Simpson's Index resulted in a range of 0.056 – 0.172. Shannon-Weiner Diversity Index (H') calculations ranged from 2.95 – 3.17. Floristic Quality Assessment Index scores ranged from 10.7 – 18. In OF plots, nitrification was 100 percent of mineralization in 2 sites (3.19 – 5.09 μg NO_3^- - N/g soil); the other four sites showed negative rates (-0.75 - -0.03 μg NO_3^- - N/g soil), thus indicative of immobilization. In SP plots, in two sites, the majority of mineralization occurred as ammonification (2.81 – 3.51 μg N/g soil), while

the other sites displayed immobilization (-4.01 - -1.34 µg N/g soil). In PW plots, low to no levels of nitrification occurred, with the exception of one site (1.73 µg NO_3^- - N/g soil), the nitrification of which is likely attributed to the presence of an aerobic layer in inundated conditions. Almost all mineralization occurred in the form of ammonification (0.09 – 7.56 µg N/g soil). Canonical correspondence analysis indicated vegetation plays a more dominant role in allowing differentiation of sites, likely due to the variability of soil parameters studied. High percent cover of species and presence of diverse species indicate functions of sediment retention and wildlife habitat should be provided. While variable, soil data show processes of nitrification, ammonification and immobilization are occurring. Data collected will provide a baseline of these sites for further study to assess development of mitigation sites.

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CHAPTER 1
INTRODUCTION

Introduction to wetlands and history of their regulation

Currently wetlands are the only ecosytem in the United States to receive comprehensive federal protection, both on public and private lands (Gutrich and Hitzhusen 2004). Under Section 404 of the Clean Water Act, the US Army Corps of Engineers (COE) regulates the placement of fill material into all jurisdictional waters of the United States, including wetlands. Typically wetlands are located in the headwaters of streams and along riparian corridors adjacent to tributaries and rivers. Wetlands are defined as "those systems that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation adapted for life in saturated soil conditions" (COE Wetland Delineation Manual 1987). An undisturbed wetland must contain the parameters of presence of dominant hydrophytic species, hydric soils and indicator(s) of hydrology to be delineated as a wetland and protected under Section 404 of the Clean Water Act.

Federal regulations in regards to the protection of these waters have become increasingly stringent over the past decade. Less than five years ago, the placement of fill material and subsequent loss of three acres of wetlands could occur under a general permit known as Nationwide Permit (NWP) 26. This permit was developed on a national basis and was determined to have no more than minimal adverse environmental impact when issued on both individual project basis and a cumulative watershed basis (61 FR 65974). Due to revisions and additional scrutiny concerning this permit, NWP 26 is no longer valid and the majority of other NWPs currently allow no more than 0.20 hectare (0.5 acre) of wetland loss in association with development and construction activities. Proposed fill in excess of 0.50-acre is typically reviewed on a individual permit basis and prior to issuance of a permit the applicant must, among other requirements, demonstrate the proposal is the least environmentally damaging practicable alternative and they have avoided, minimized and compensated for the loss of waters in association with the proposal to the maximum extent practicable (45 FR 85344).

Wetland functions and values

Wetlands receive federal protection because of their ability to provide environmental functions and values unique to this ecosystem. While it is difficult to quantify the functions provided (Hruby 1999) by these systems, scientific research has well-documented evidence of the ability of wetlands to perform such functions as reducing sediments and pollutants in downstream waters, providing habitat and high levels of biological diversity, reducing floodwater volume, providing groundwater recharge during times of drought and providing aesthetic values. The functions provided by wetlands can be organized into three main categories and include 1) hydrologic functions including short and long-term storage of water, and maintenance of a high water table; 2) biogeochemical functions including the transformation and/or cycling of elements, the retention or removal of dissolved substances, the accumulation of peat and the accumulation of inorganic materials; and 3) maintenance of habitat and food webs including the presence of vegetation that supports wildlife through food and habitat sources and the maintenance of energy flow (National Research Council 1995). It is because of these performed functions and associated values provided to society that wetlands receive federal protection.

Compensation requirements to replace lost wetland functions and values

Under current regulations, the loss of more than 0.04 hectare (0.10 acre) of wetland in association with any proposal requires compensatory mitigation in the form of either on or off-site creation, restoration or preservation of wetlands intended to provide functional replacement for those waters lost during construction activities. While mitigation is required, many sites have failed for numerous reasons, including low numbers of or no compliance inspections by the regulatory agency and inability of the regulatory agency to incorporate conditions into an issued permit that are scientifically defensible and written to require the functional replacement of those wetlands lost (Race and Fonseca 1996). The National Research Council (2001) concluded based upon a review of wetland permits issued nationwide, wetland mitigation is not always successful. This is due in part to several reasons, including the replacement of different functions in different watersheds, unclear or unenforceable performance standards set by the regulatory agencies and lack of compliance to ensure mitigation sites are appropriately constructed.

Assurance of final success of a mitigation site is the ultimate responsibility of the regulatory agency, as described above. However, in order to ensure the ultimate success of a mitigated wetland system, which is the functional replacement of those wetlands lost, a wealth of factors must be taken into consideration during planning and implementation of the project. All plans and actions should be taken with the goal of functional replacement in mind. Success in the context of replacing those sites lost with similar sites in the same watershed is difficult to achieve. Factors that will affect the success of implementing a mitigation plan may include, but are not limited to, the fact that natural systems may not respond as expected to construction techniques utilized during implementation of the mitigation plan (i.e. construction of berms, excavation activities) (Zedler 1996). Many times attempts are made to introduce hydrology into an area that will not support a natural hydrologic balance without human intervention and control. Over-engineered, constructed wetlands in contrast to restored wetlands are more likely to not achieve the standards of a natural wetland and would therefore provide less natural diversity and not appropriately replace the functions and values of natural wetlands. This will in turn have a cumulative effect on the overall landscape of watersheds (Bedford 1996). Because natural wetlands depend on varying levels of water and seasonal drawdown to support plant species, artificially created sites that do not provide this drawdown may fail to provide similar functions and values as natural wetlands (Reaves and Croteau-Hartman 1994).

Mitch and Wilson (1996) also recognize the need to understand wetland functions and to design a system that is as self-sustaining as possible. However, they have determined the typical five year monitoring period required by most permit conditions is insufficient to determine if mitigation is achieving success. They state a time frame of 15 to 20 years of monitoring would be more appropriate to adequately assess success. Others contend that 5-10 years may be a suitable monitoring timeframe for those systems that are expected to achieve low diversity and/or provide few functions; however, the development of high diversity, high performance systems may require 20 to 100 years to reach full potential (Zedler and Callaway 1999).

Several studies advocate the identification and use of natural wetlands that may serve as references to compare mitigated systems. Studying reference systems has the ability to provide a means of learning what mechanisms of the system are necessary to provide specific functions in the watershed. This understanding and subsequent application of principles learned should decrease the likelihood of mitigation failures (Whigham 1999). An approach termed the hydrogeomorphic (HGM) assessment method has been used in the past to evaluate the functions being performed by a natural wetland prior to its disturbance and then to estimate how functions change after impact at the natural site and subsequent creation/restoration of the mitigation site (Rheinhardt, Brinson and Farley 1997). Reference wetlands should encompass the variation of known wetlands within a region (Brinson and Rheinhardt 1996). OEPA has completed and is in the process of several additional studies aimed at the goal of establishing and recognizing those wetlands in the region of this study that may be referred to as reference wetlands. That agency's study of reference wetlands has allowed development of the Vegetation Index of Biotic Integrity (VIBI) method of assessing success of restored wetland sites (Mack 2001). While reference wetlands are now being used to compare and assess the success of mitigated sites, much of these OEPA studies and subsequent publication of technical reports took place concurrently or after field work associated with this study. Therefore, while VIBI analysis would be a useful index for assessing success of sites in this study, that method will not be used in this analysis.

Methods of assessing replaced functions and values

The role of vegetation collection and monitoring

It is recognized in some studies that the analysis of vegetation structure in wetland does not indicate what functions, if any, the mitigated wetland system is performing. Structure of a system is assumed to correlate strongly with function; however, this is difficult to show directly and may lead to a false determination of the site's success (i.e., diverse structure would imply diverse functions are performed when this may not necessarily be the case). Cole (2002) discussed six functions of wetlands and whether percent plant cover may be an indicator of how well a mitigated wetland would provide each of these functions. This study states the percent cover of herbaceous plant species found at a mitigation site will not provide insight to how well that site provides the functions of short and long-term surface water storage, maintenance of a high water table or accumulation of inorganic sediments.

In regards to those functions that may be attributed to plant presence and cover, Cole reports previous studies have cited the conclusion that higher percent cover of herbaceous species correlates to higher rates of pollutant, heavy metal and sediment removal. The studies have shown it is not necessarily the plants themselves that retain these contaminants, but instead the microorganisms that attach to the stems, leaves and roots of hydrophytic plants. Nonetheless, a higher percent cover of plants has been recognized to provide a higher density of microorganisms. The presence of plants and certain plant species (not necessarily cover of those species) may provide insight into the functions of nutrient cycling and transformation. In addition to contaminant removal and role(s) in nutrient cycling, the presence of certain plant species will also provide insight into the ability of the wetland to provide various scales of habitat quality to wildlife (Brown 1999). Payne (1992) and Martin et al. (1951) have described those plant species that are recognized as excellent, good, fair or poor for wildlife use.

During construction of a mitigated wetland, methods of establishing wetland plant species include passive revegetation, use of hydric topsoil containing a viable seed bank, container plantings, and seeding. A study conducted on constructed wetlands in northwest Ohio concluded the passive revegetation method resulted in good vegetative cover of plant species, but a low percentage of the species were hydrophytic (Luckeydoo et al. 2002). Another study focused on three-year old wetland creation sites. While species richness was similar to nearby natural wetlands, the created systems were characterized by dominant levels of the invasive species *Typha angustifolia*, *Phragmites australis* and *Lythrum salicaria*. The presence of these species in the early years of wetland development is not uncommon, but the eradication of those species before they out-compete other native hydrophytic species is essential to overall success of the sites (Confer and Niering 1992).

Use of hydric top soil during wetland restoration/creation activities appears to be one of the most important factors controlling successful establishment of hydrophtyic plant species (second only to appropriate control of hydrology and providing the wetland with appropriate and varying zones of inundation as required for each plant species). Hydric soil with a viable seed bank has proven in numerous studies to be the most effective method of establishing vegetation in a mitigation site (Ashworth 1997, Burke 1999, Heaven et al. 2003, Stauffer and Brooks, 1997). Establishment and continued successful growth of a diverse plant population may be attributed to a seed bank containing seeds of species that respond to various hydrologic conditions. Use of a hydric soil seed bank will encourage the establishment of a diverse plant community, thereby increasing the likelihood that species providing good habitat value to wildlife are established. Species from thirteen genera in a study conducted Brown and Bedford (1997) were documented to provide excellent, good or fair habitat value to wildlife. In contrast, a study focused on wetlands that were not constructed by using salvaged organic soils from destroyed wetlands. Results show soil organic matter concentrations were significantly less in created systems. This type of construction practice can result in wetlands that unable to function as natural systems for many years or even decades (Shaffer and Ernst 1999).

Methods of assessing replaced functions and values

The role of environmental (soil) collection and monitoring

As stated above, wetlands provide a function of biogeochemical cycling. As a result, wetlands are able to act as a source (causing net loss of a substance), a sink (causing retention of a substance) or a transformer of nutrients (National Research Council 1995). In wetland systems, rates of net production and accumulation of organic matter exceed decomposition rates, and therefore these systems commonly serve as sinks for nutrients, as they are able to store large amounts of nutrients. This is due primarily to large amounts of vegetative biomass production and because in anaerobic saturated and/or inundated conditions, rates of decomposition are dramatically reduced (Craft 1997). Therefore the presence of plants within a mitigation site provides insight, while poorly understood, into the functions of nutrient cycling and transformation (Adams 2003). The presence of plants within a mitigation site may provide insight into the functions of nutrient cycling and transformation. Nitrogen may be removed by conversion of NO_3^- to N_2 in a process called denitrification or may be conserved within a system by plant and microbial uptake of inorganic nitrogen and sedimentation/filtration of particle bound N (Davidsson and Stahl 2000). Microbial mediated denitrification removes nitrogen from the system while mineralization, immobilization and nitrification conserve N in the system as NO_3, NH_4^+ or organic N (Matheson et al. 2003). The determination of nitrogen mineralization and nitrification rates has been recognized as useful to provide insight into functions of a system's nitrogen cycling. Providing a supply of nitrogen through the process of mineralization is important to soil fertility and supporting vegetative growth (Duncan and Groffman 1994). In contrast, while the process of immobilization may provide positive effects to water quality, microbial immobilization of nitrogen results in an unavailable nitrogen source to plants. If immobilizing bacteria are present in soil, their assimilation of nitrogen has been shown to occur at a faster rate than that of plant uptake, thus affecting availability of nutrients to plants (Yevdokimov and Blagodatsky 1993).

Soils with higher organic levels have been determined to cause higher levels of nitrate removal, which is an important function performed by wetlands. Intuitively, natural wetlands will provide a larger amount of soil organic matter, as this matter has been accumulating for many, many years. Bishel-Machung et al. (1996) confirmed this in a study conducted in Pennsylvania where soil organic matter content was compared between natural and reference wetlands. Larger amounts of organic material contain higher levels of microbes that are active in removal processes (Davidsson and Stahl 2000). In order for a constructed wetland system to function effectively in the cyling of nitrogen via mineralization and nitrification, Duncan and Groffman (1994) also recognized the importance of the establishment of microbial communities.

They concluded the use of organic substrates and the establishment of vegetative cover ensured wetlands would develop a microbial community that ensures nutrient cycling. This ensures the water quality functions of the wetland are performed. Vegetation plays a crucial role in the establishment of organic accumulation, and the quality and quantity of organic matter (carbon) supplied by plants will determine the activity level of microbes, thereby affecting mineralization and immobilization rates (Knops et al. 2002).

By studying organic matter accumulation in freshwater emergent and open water wetlands in Oregon, Shaffer and Ernst (1999) concluded constructed wetlands do not meet the criteria of natural systems. A study of mitigation sites varying in age fromone to 15 years after construction concluded organic matter levels, and subsequently nitrogen, phosphorus, and carbon levels were lower in constructed than natural refernce wetlands (Craft et al. 1988). In a more recent study, Craft et al. (1999) determined 25 year old constructed *Spartina alterniflora* marshes are very similar in structure and function to natural areas. Shaffer and Ernst (1999) recognized the importance of transferring soils from impacted wetlands to the mitigation site and concluded significantly lower amounts of soil organic matter in created wetlands studied is likely due to poor planning and poor management of hydric soil during construction. While processes may not be equal in constructed and natural wetlands, another study concluded retention of nitrogen will begin as soon as organic matter commences accumulation and vegetation is present. This can be as early as the first to third year of establishment (Craft 1997). Similarly, Gilliam and Fisher (1995) gathered soil data at Green Bottom Wildlife Management Area (WV) and concluded mitigated wetlands progress towards natural wetland systems after inundation. They found inundated soils respond quickly to introduced anaerobic conditions, as the process of nitrification is reduced, but net nitrogen mineralization continues.

Zak and Grigal (1991) studied nitrification, denitrification and mineralization in upland, including pin oak, old field and savannah, and wetland ecosystems. They found that extractable NH_4^+ and NO_3^- rates were significantly different among the different ecosystems. Of the systems studied, negative daily rates of net N mineralization were found only for the pin oak system. They stated this could be a result of one of two processes: denitrification or immobilization. Annual rates of nitrification were lowest in the wetland system. Significant differences within each ecosystem were found over time. Nitrogen availability, and therefore cycling of nitrogen, in the wetland ecosystem is affected by soil organic matter chemistry, seasonal inundation and anaerobic conditions.

Objectives

The objectives of this study were, in general, to assess vegetative and environmental parameters of mitigated wetland sites and to assess if the analysis of those parameters collected can be used to determine functional success of these sites, as well as to draw conclusions concerning differences in the progression of each of those sites studied. Specifically, the objectives of this study are 1) to compare vegetation present in six mitigation wetland sites located in the upper Scioto River drainage basin in central Ohio and assess parameters including richness, diversity, and percent of native, invasive and hydrophytic species; 2) to compare environmental soil data, including soil moisture, available nitrogen pools and fluxes, collected from three zones of varying inundation levels located in each of the wetland systems; 3) to draw conclusions concerning what factors may have affected those significant differences, if any, among each of the wetlands studied and 4) to draw conclusions concerning whether the studied wetlands are functioning to provide wildlife habitat, to remove pollutants from the watershed, and provide functions of nutrient cycling and transformation.

CHAPTER II
MATERIALS AND METHODS

Site Selection

Six sites located in Franklin, Delaware and Union Counties, Ohio and in the upper Scioto River drainage basin were chosen for study. These sites were chosen based on the following criteria: (1) they are each located in the upper Scioto River drainage basin; (2) some or all of the site's history is present in records at the Huntington District Corps of Engineers' office; (3) each has been constructed and a source of hydrology has been successfully supplied to the sites; and (4) the compilation of the six chosen sites provide 2 sites each for sites that are (a) four to five years old; (b) six to seven years old; and (c) 10 or more years old. A detailed discussion of each of these sites is presented in Chapter III.

Field Methods and Collections

During initial field review of the sites, a thorough walkover of each site was completed. Representative areas to establish transects were determined and at least three but no more than six transects were established at each separate sites. Transects were established by the following method: the transect originated at a location in uplands approximately 10 meters from the edge of the wetland and continued until standing water with no vegetation was observed. Transects ranged in length from 60 to 110 meters.

Five of the six study sites were comprised primarily of only herbaceous vegetation. Vegetation was sampled in 1-meter square quadrats placed every 10 meters along the established transect. Percent cover and frequency were recorded for each species. From these values, relative cover, relative frequency and importance values were calculated for each species. Only two of the six sites contained tree species. At these sites, trees with diameters greater than 10 cm (4 in) at breast height (dbh) were identified and measured. Three of the six sites contained minimal percent cover of species in the shrub layer. Presence of these species was documented.

Soils were sampled from each of the transects previously established for the collection of vegetation data. Along each transect at each site, soil samples were collected from plots in the wetland that are seasonally saturated/inundated (seasonally pooled - SP) and from plots in the wetland that are permanently inundated (permanently inundated wetland – PW). For each plot, four soil cores were randomly taken to a depth of 10 cm and homogenized. In addition to the SP and PW plots, at least one plot from each of the six study sites was taken from the old field (OF) areas surrounding the mitigation wetlands. Soils from each plot were divided into two separate samples – one to undergo extraction as quickly as possible and the other to be incubated for 28 days and then extracted for nitrogen analysis. All samples were stored on ice for transportation from the field to the laboratory.

Laboratory Analysis

Those plant species not able to be identified in the field were taken back to the laboratory for identification.

Laboratory analysis in regards to collected soil specimens was conducted to determine pre and post-incubation levels of NO_3^- and NH_4^+. This data was then used to determine net mineralization and nitrification. Before extraction, percent moisture of the samples was determined by placing ~ 15g of wet soil sample in a beaker from each plot. Samples were dried at 100˚C for approximately 48 hours and then re-weighed. Percent moisture was determined by the following equation: 100 – [(dry weight/wet weight) * 100]. To conduct extraction of both pre and post-incubation soil samples, approximately 10 g of each soil was extracted with 100 ml of 1*N* KCl. These extracts were then analyzed for NO_3^- and NH_4^+ with a Bran+Luebbe TrAAcs 2000 automatic analysis system. Net nitrogen mineralization was then calculated through use of the following equation: Mineralization = post incubation (NO_3^- and NH_4^+) – pre-incubation (NO_3^- and NH_4^+). Net nitrification was calculated through the use of the following equation: Net nitrification = post incubation NO_3^- - pre incubation NO_3^- .

Statistical Analysis

In order to determine similarities between communities, the community coefficient (CC) was calculated. To provide CC values for relationships among the sites, Sorenson's calculation using presence was used: 2C/(A + B), where C is the number of species present in both wetland A and B, A is the number of species in wetland A and B is the number of species in wetland B.

Diversity and evenness are two important components used to assess the quality of vegetation in aquatic and terrestrial systems. To determine diversity between the sites, the Shannon-Weiner diversity index (H') was calculated for each site where $H' = - \sum [(p_i)(\ln p_i)]$. To evaluate the evenness of sites, the Shannon Evenness index (J) was calculated as, $J = H'/\ln S$, where S is the total number of species in the plot.

While the Shannon-Weiner index and evenness scores provide insight into the number of species in a community and their distribution, each species is given the same weight in these calculations and therefore the resulting scores do not allow differentiation of tolerant and sensitive species. The Floristic Quality Assessment Index (FQAI) method was developed based on the premise that the quality of a community can be determined by assessing the level of tolerance, or the degree of conservatism, that is expressed by plants in that community. Coefficients of conservatism (C of C) have been assigned to nearly all native plants in the State of Ohio. While it was recognized during development of this method that some subjectivity of the investigators could influence the scores assigned to each species, it should also be recognized the investigators have broad and intensive field knowledge of plant species in Ohio. Therefore, while assignments of C of C values could have been subjective, now that these designations have been made, the FQAI calculations can be completed consistently and objectively. The FQAI has been found to be very accurate in assessing wetland disturbance and quality. C of C scores range from zero to 10 and the required traits that must be exhibited by species to receive its specific C of C are identified in Table 2. After assigning a C of C value to each species, the FQAI is calculated by the following equation: $I = \sum (CC_i) / \sqrt{(N_{native})}$, where I = FQAI score, CC_i = the coefficient of conservatism of plant species *i* and N_{native} = the total number of native species occurring in the community being evaluated (Andreas et al. 2004).

Statistical analysis consisted of the use of the direct gradient multivariate ordination technique canonical correspondence analysis (CCA). To perform this analysis, the program Canoco for Windows 4.5 was utilized (Gilliam and Saunders 2003). During this analysis, environmental data and species data from each of the sites was combined to produce ordination diagrams. CCA is a direct gradient analysis, which means the distribution of species along studied environmental gradients may be determined from the output of this technique. In order to interpret CCA diagrams, it is necessary to understand the following: arrows represent environmental variables and the length of an arrow is directly related to the importance of that variable; the direction of an arrow indicates how well the environment is correlated with species composition; the angles between arrows indicates the correlation between variables; the location of sites relative to arrows indicates the more dominant or important environmental characteristics of sites; and the location of the species scores relative to the arrows indicates the environmental preferences (Palmer 1993).

Table 1. Characteristics of sites chosen for this study. All information obtained from files located in the Huntington District's US Army Corps of Engineers office.

Site	Age	Existing wtlnds	Restore Hydrology	Soil types
Honda (1)	4	Yes	Block ditches, berms	Hydric
Med (2)	10	Yes	Watershed, excavate	Hydric
New Albany (3)	7	Yes	berms, watershed	hydric
ODOT (4)	5	yes	berms, watershed	Hydric
ODOT WCA (5)	6	Yes	watershed, historical	Hydric
Ross (6)	11	No	berms, watershed	Hydric

Table 1. Continued.

	Establish Vegetation	Monitor vegetation	Results	Monitor wildlife
1	seed bank	4 1m^2 plots	> 50 % hydrophytes	no
2	Stockpiled soils, seeding	Limited	Water quality	no
3	plantings/seed bank	5 1X2 m quad	57 of 58 are hydrophytes	no
4	existing wetland, seeding	10 plots	dominant hydrophytes	42 birds, 6 salamanders
5	seed bank, seeding	Observation	dominant hydrophytes	No
6	Stockpiled soils, seeding	List species	dominant hydrophytes	20 birds

CHAPTER III
SITE HISTORY

Each wetland chosen for study will be described in detail below. Characteristics of each wetland including age at time of study, whether wetlands existed on-site prior to construction of the mitigation wetlands, how hydrology was restored/supplied to each area, soil types at each site prior to restoration, how vegetation was established, monitoring methods (vegetation, wildlife, water quality) and results of monitoring have been summarized for ease of comparison (Table 2).

Site 1 (Honda site) - Wetlands adjacent to an unnamed tributary of Flat Branch – Union County, Ohio (vegetation sampled at year 4 following completion of construction)

Site History: A 44.5 hectare site, located along State Route 739 in Marysville, Union County, Ohio was investigated for the presence of waters of the United States prior to application to the COE to place fill material into waters on-site. As identified in the Soil Survey of Union County, Ohio (1975), the site consists of Pewamo, Napanaee, Blount and Morley soils. Several unnamed ephemeral and intermittent tributaries and five wetlands were identified on-site. The largest wetland, comprised of 3.8 hectares, was located adjacent to Flat Run and its tributaries. Dominant species included *Quercus palustris* (Pin Oak), *Q. bicolor* (swamp white oak), *Carpinus caroliniana* (American hornbeam), *Carya ovata* (shag-bark hickory), *Lindera benzoin* (spice bush), *Typha latifolia* (cattail), *Juncus effusus* (soft rush) and *Cirsium pumilum* (thistle). Soils exhibited low chroma with mottles. Primary hydrology indicators included saturated soils, water stained leaves and drift marks. Approximately 0.28 hectare of emergent wetlands and 1.2 hectares of detention basin were also identified within the proposed project boundaries, for a total of 5.3 hectares of jurisdictional waters at the site.

Mitigation: During project implementation, all wetlands described above were unavoidably impacted by the placement of fill material. In order to compensate for the loss of wetlands associated with this project, a 34.8 hectare site was examined in order to determine the potential of wetland restoration or creation (Figure 1). A total of five wetlands, comprising 1.2 hectares, were identified on-site. Scrub/shrub and emergent species were dominant in the wetland areas and included *Phalaris arundinaceae* (reed canary grass), *Fraxinus pennsylvanica* (Green Ash), *Ulmus americanus* (American Elm) and *Acer rubrum* (Red Maple).

Table 2. Description of coefficients of conservatism (C of C) used in the FQAI calculations (Andreas et al. 2004)

C of C	Description
0	Species with a wide range of ecological tolerances. May be invasive, non-native taxa (eg PHAR) or native taxa that are typical of a ruderal community (AMAR).
1 – 2	Widespread species not typical of a particular community like SOCA or *Impatiens capensis*
3 – 5	Species with an intermediate range of ecological tolerances, often found in a stable native community, but may also persist in disturbed areas
6 – 8	Species with narrow ranges of ecological tolerances that are often found in a stable community (e.g. *Cephalanthus occidentalis)*
9 – 10	Species with narrow ranges of ecological tolerances and habitat requirements.

Figure 1. Site location map of the Honda site. This site is located in Allen Township, Union County, Ohio and on the East Liberty 7.5 minute USGS quadrangle.


Honda Site
Middleburg
Darby Creek
Pottersburg
ALLEN
ZANE
MONROE
LOGAN CO
UNION CO
SCALE 1:24 000
Mapped, edited, and published by the Geological Survey
Control by USGS and NOS/NOAA

In order to compensate for the loss of 5.4 hectares of wetlands, 8.5 hectares of wetland were proposed to be restored at this location. In order to increase soil saturation, ditches traversing the site were blocked and berms were constructed. One ditch was diverted to allow water to flow into the mitigation area. Before restoration, soils at the site consisted of Paulding silt loam, a hydric soil, and Nappanee and St. Clair silt loam, non-hydric soils with hydric inclusions (Figure 2).

Monitoring : Vegetation was monitored by establishing four 1.0 m^2 plots and three 4.0 m^2 plots. In 2000, the investigator submitted a report that determined six of the seven plots contained greater than 50 percent of wetland species. Dominant species identified included *Populus deltoides*, *Salix nigra*, *Carex lurida*, *Calamagrostis canadensis*, *Solidago odora, Fraxinus pennsylvanica*, *Robinia pseudo-acacia*, *Rosa multiflora, Crataegus* sp. and *Rhus radicans* (Burgess and Niple, 2000).

Site 2 (Medallion) - Wetlands adjacent to an unnamed tributary of Alum Creek – Delaware County, Ohio (Sampling at year 10)

Site History: During the construction of a golf course development, 3.6 hectares of jurisdictional wetlands were filled at a 242 hectare site located south of Big Walnut Road and west of Sunbury Road in Delaware County, Ohio. Of this loss, 2.6 hectares were described as emergent and 1.0 hectares were described as forested. Over 28.3 hectares of jurisdictional wetlands were avoided and preserved in association with the development plan. The required mitigation was provided through the creation of several wetland areas on-site, only two of which are included in this study. Because this site is located directly within and adjacent to an active golf course, it was uncertain whether the effects of pesticides and/or fertilizers may affect parameters at this site that are not affected at other sites, as disturbance type at other study sites would be expected to be less severe. In a 1998 study designed specifically to determine if water quality directly adjacent to golf courses is significantly adversely affected, hundreds of samples were taken and studied for the presence of specific chemicals. While many of the samples tested positive, levels were found to be relatively low (Ryals et al. 1998). Therefore, because this site represents a good example of a mitigated wetland in the upper age category needed for this study, it was included and it is hoped the differing adjacent land use does not affect data collected in this study.

Figure 2. Soil types located at the Honda site as identified by the Soil Survey of Union County (1975).

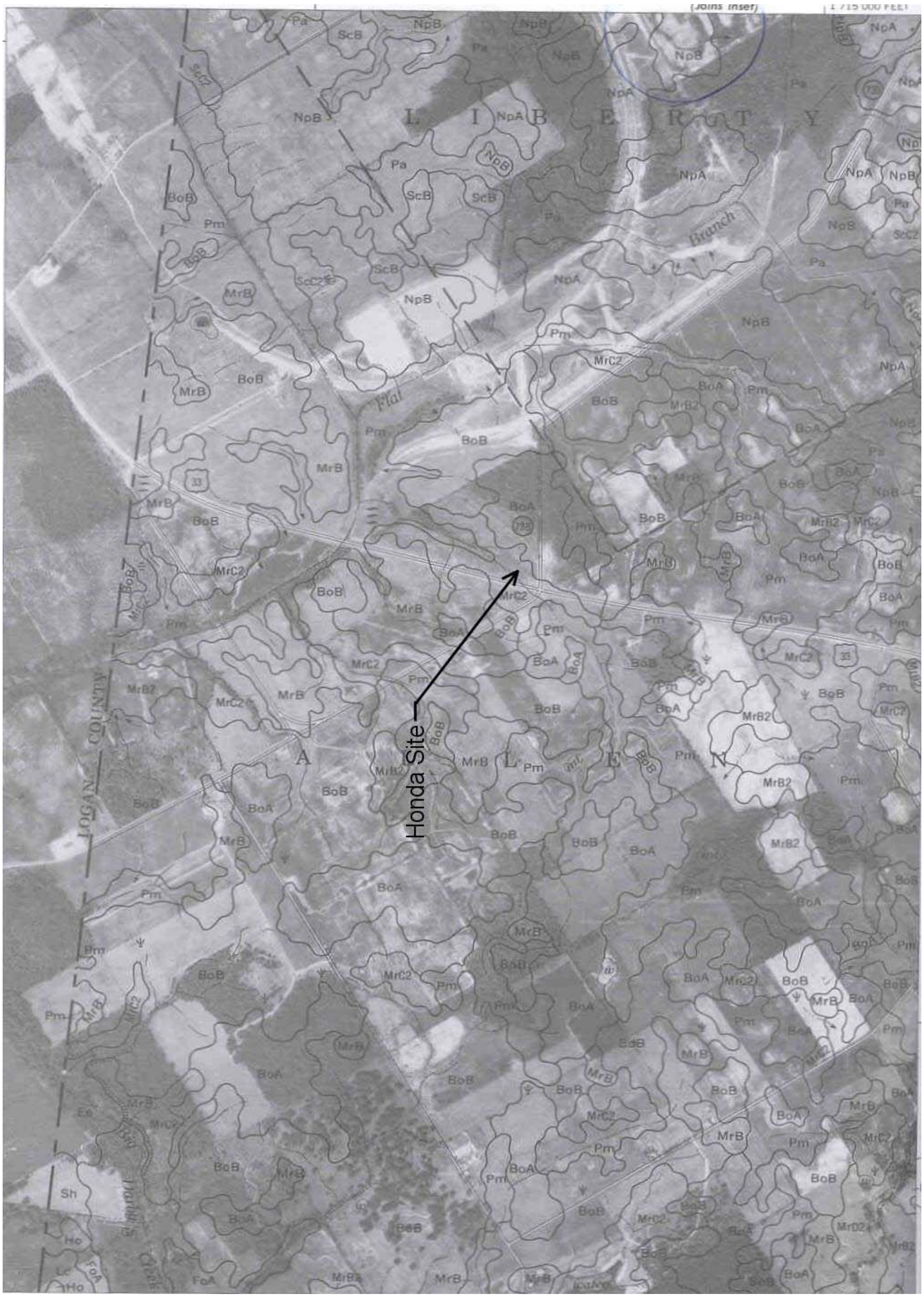
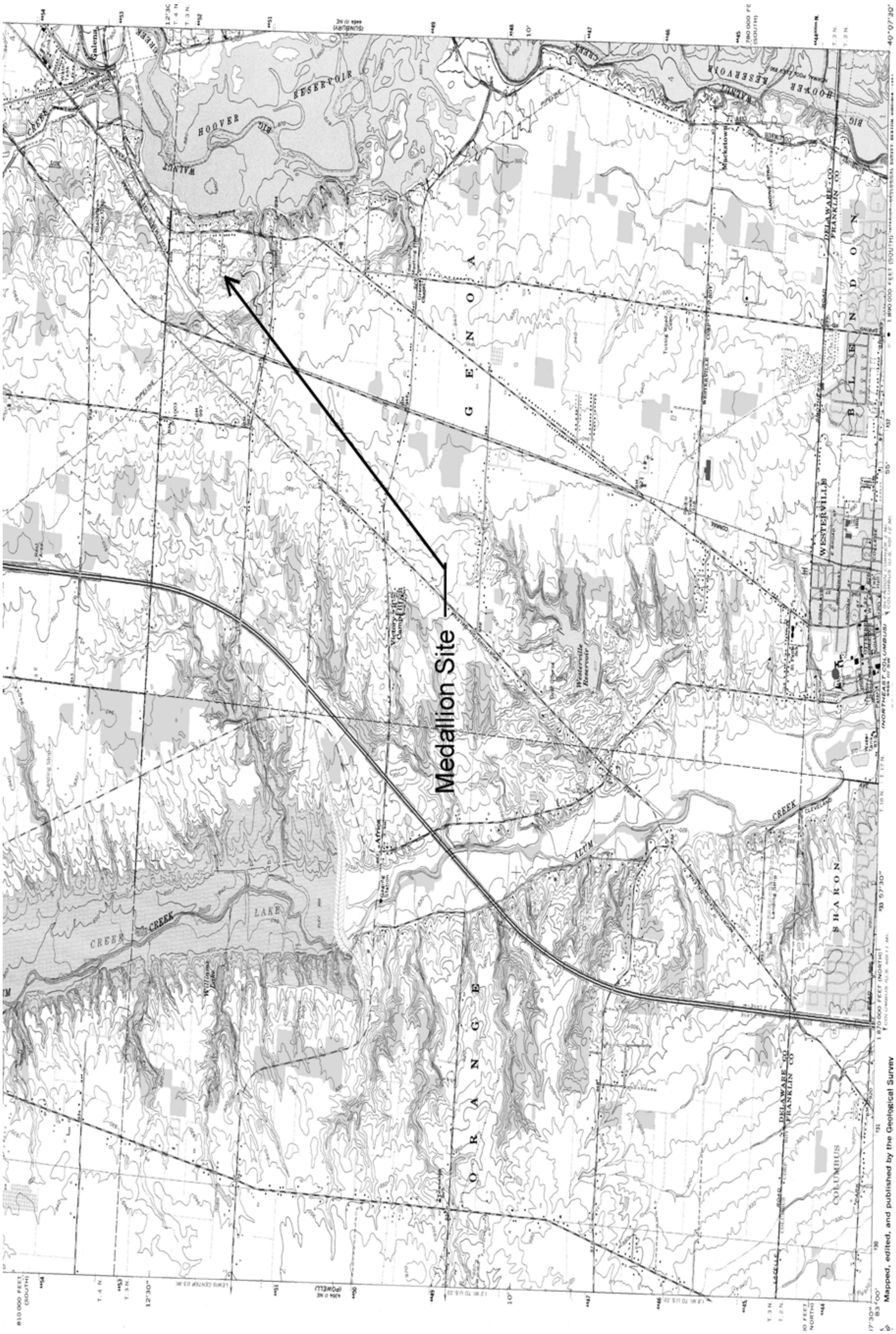

(Joins inset)
1 715 000 FEET
L I B E R T Y
Branch
Flat
Honda Site
A L L E N
LOGAN COUNTY

Figure 3. Site location map of the Medallion site. This site is located in Delaware County, Ohio and on the Sunbury 7.5 minute USGS quadrangle.


Medallion Site
HOOVER RESERVOIR
G E N O A
O R A N G E
WESTERVILLE
SHARON
ALUM CREEK
Westerville Reservoir
COLUMBUS
DELAWARE CO
FRANKLIN CO
Mapped, edited, and published by the Geological Survey

Mitigation: 5.5 hectares were created or restored on-site at the Medallion Golf Course to compensate for 3.6 hectares of jurisdictional wetland loss in Delaware County, Ohio (Figure 3). Soils on-site consist of Pewamo and Condit silt loam, hydric soils, and Bennington silt loam, a non-hydric soil with hydric inclusions (Figure 4). Hydric soils compose approximately 40 percent, or 97.2 hectares, of the development site. The applicant proposed to restore/create twelve separate wetlands to comprise the total required mitigation of 5.5 hectares. In herbaceous wetlands, the applicant proposed to establish three zones of varying inundation/saturation and proposed to establish plantings including *Sagittaria latifolia*, *Alisma* sp., *Rumex* sp., *Scirpus atrovirens*, *Eleocharis* sp., *Juncus* sp and *Carex* sp. Excavation would take place to a maximum depth of 2 m below the average water level. Wetlands were graded so that depressions would be created that are capable of holding rain water and water from other discharge sources. Soils were taken from wetlands that were destroyed during construction processes. They were either stockpiled or moved directly to the new wetland areas to be restored, where they were spread to a depth of approximately 15 cm.

Monitoring: Completion of construction at the mitigation sites occurred in 1993. In 1998, a report was submitted to the COE that documents primarily water quality at the site. Water quality parameters were studied to determine if those chemicals used at the golf course had adversely affected water quality. No levels unacceptable to the Ohio Environmental Protection Agency were reported. While this document was identified as a report designed to identify vegetative monitoring results as well, data was limited and did not include results from those wetlands chosen for this study (The Medallion Club 1998).

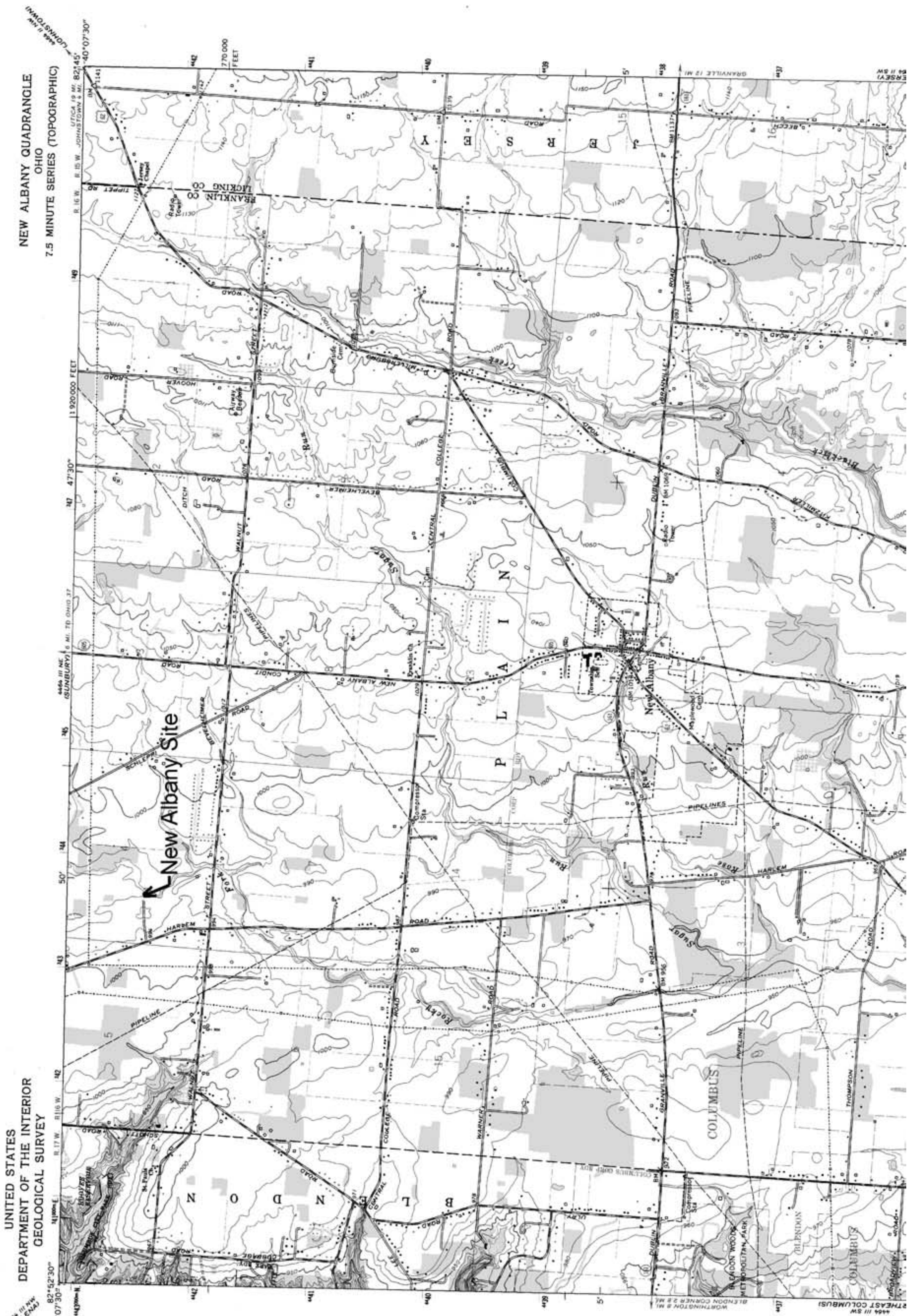
Site 3 - Wetlands adjacent to an unnamed tributary of Rocky Fork Creek – Franklin County, Ohio (sampling at year 7)

Site History: A 42.9 hectare parcel, located south of State Route 161 between Rocky Fork and State Route 105 in New Albany, Franklin County, Ohio was investigated for the presence of waters of the United States in anticipation of constructing a residential development. In a delineation performed in 1994 (Envirotech), it was determined that 6.5 hectares of wetlands were located at this site. In order to develop this parcel, 3.2 hectares of wetland were filled, of which 0.72 hectares were forested, 0.8 hectares were scrub-shrub and 1.62 hectares were emergent.

Figure 4. Soil types at the Medallion site as identified by the Soil Survey of Delaware County (1969).


HOOVER
RESERVOIR
Medallion Site

Figure 5. Site location of the New Albany site. This site is located in Plain Township, Franklin County, Ohio and on the New Albany USGS 7.5 minute quadrangle.

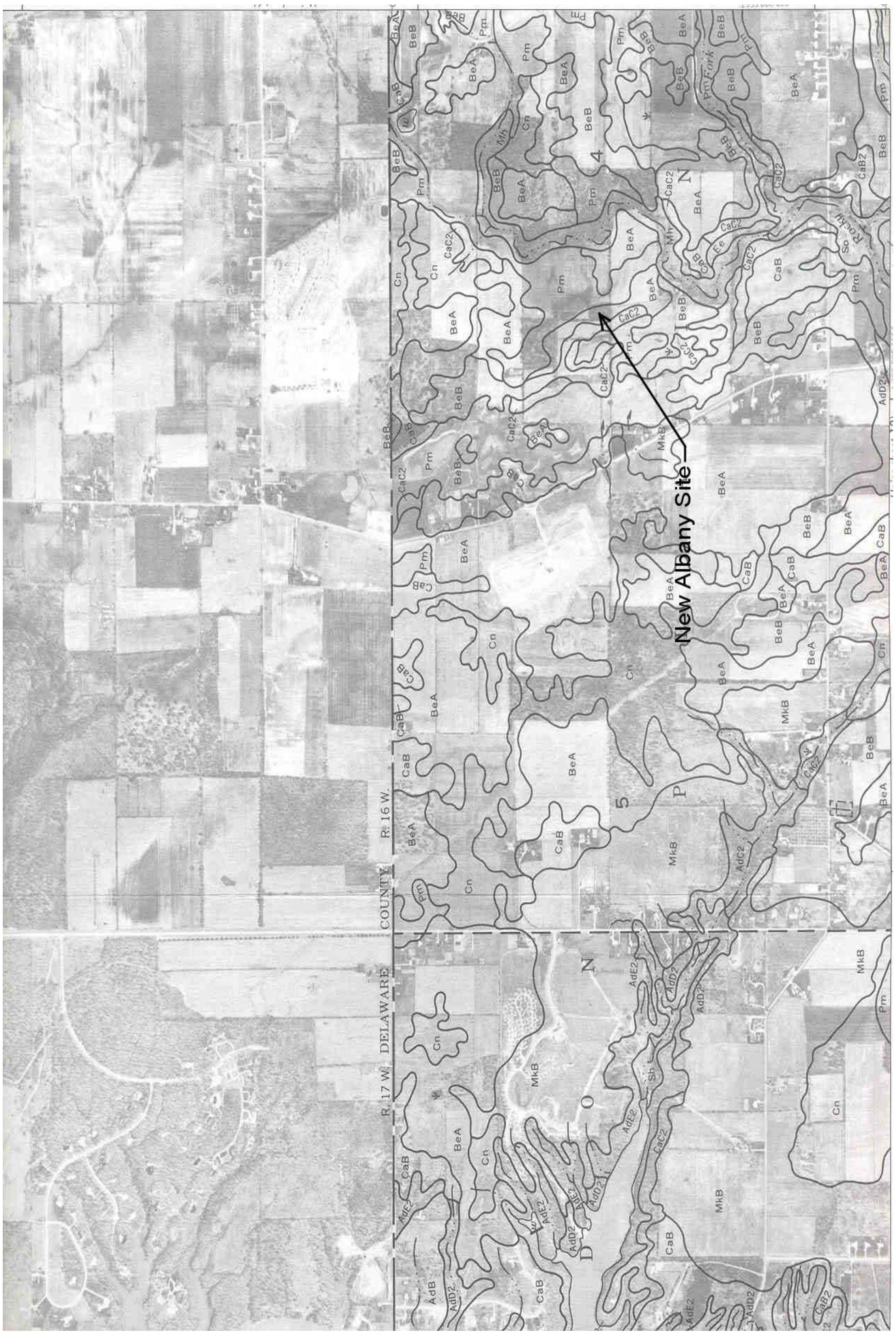

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
NEW ALBANY QUADRANGLE
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)
New Albany Site
New Albany
COLUMBUS

Mitigation: Off-site mitigation for partial impacts was proposed at a parcel located along Harlem Road and north of Walnut Street in New Albany, Franklin County, Ohio (Figure 5). On the 42.9 hectare site, 2.0 hectares of jurisdictional wetlands were identified. In the area specific to this mitigation project, one wetland totaling 1.3 hectares was identified. While this area was proposed to be enhanced during project execution, no credit for this work was requested. This wetland was dominated by *Phalaris arundinaceae*, *Polygonum pennsylvanicum* and *Bidens sp*. Hydrology indicators included drainage patterns and inundation while soils were mottled and mapped as Pewamo silty loam (Figure 6).

A total of 3.9 hectares of wetlands were proposed for restoration, primarily through the activity of limited excavation. Of this total, 1.08 hectares would contain forested habitat, 1.3 hectares would consist of scrub-shrub habitat and 2.4 hectares would consist of emergent habitat. Berms were constructed to direct and retain water in the mitigation areas and to prevent the flooding of adjacent areas. Hydrology was expected to be supplied by the existing drainage from surrounding tributaries, which contribute over 200 acres of drainage to the site. Regular inundation or saturation of wetland areas was expected to occur as a result of the surrounding drainage, precipitation and overland flow. Excess water would be removed through overflow structures and directed toward Rocky Fork Creek. Proposed planting included various native tree, shrub and emergent species, which were chosen based primarily on their wetland indicator status (primarily FACW or OBL) and their anticipated value to wildlife (the applicant indicated most chosen species have previously demonstrated high value to wildlife.) In addition, it was anticipated the seed bank should contribute to plant community development.

Monitoring: Vegetation was monitored by establishing five 1m X 2m and four 5m X 5m quadrants. Construction was completed in 1995 and the 1999 5th year monitoring report indicated that one quadrant contained 83% hydrophytic vegetation, while the remaining contained 100% hydrophytic vegetation. A small portion of this wetland was dominated by *Quercus sp* and *Acer rubrum*. (This area was not included in the study because it contributed only a small amount of acreage to the entire parcel). An overall flora assessment of the site identified 58 species, 57 of which were reported to be hydrophytic. Dominant plant species were identified as *Polygonum amphibium, Lemna minor*, *Wolffia sp*., *Phalaris arundinaceae*, *Salix nigra* and *Leersia oryzoides*. Wildlife observation included the identification of 26 birds, 2 amphibians and 3 mammals (EMH & T, 1999).

Figure 6. Soil types located at the New Albany site as identified by the Soil Survey of Franklin County (1980).


New Albany Site
R. 17 W. DELAWARE COUNTY R. 16 W.
Rocky
Fork

Site 4 - Wetlands adjacent to Big Darby Creek, Union County, Ohio (sampling at year 5)

Site History: During the proposed relocation of State Route 33 in Logan and Union Counties, Ohio, 12 jurisdictional wetlands totaling 1.6 hectares were lost as a result of filling activities. While a delineation of the affected sites was not available, information concerning the functions performed by this systems was reviewed. According to the applicant's provided information, wetland systems filled as a result of this project functioned primarily to retain flood waters, sediments and toxicants and to remove or transform nutrients.

Mitigation: Compensation for proposed impacts was proposed to occur through the on-site restoration of 2.5 hectares of wetlands, to be preserved and protected in perpetuity within an 8.5 hectare mitigation site (Figure 7). Soils comprising the site included Latty silty clay, a hydric soil, and Fulton silt loam, which may have inclusions of Latty silty clay in depressions and drainages (Figure 8). One existing wetland, comprised primarily of *Typha angustifolia* in the emergent layer and various tree species including *Fraxinus pennsylvanica*, *Salix nigra* and *Populus deltoides*, extends along the northern portion of the mitigation site. This existing wetland was proposed to be expanded through berm construction along the low sides of the mitigation area. An adjustable water control structure would be installed to retain additional surface water and expand surface saturation and flooding. Low slopes were designed in order to create a smooth transition from the permanently flooded areas to the seasonally saturated or inundated areas. No deep water areas existed at the site prior to restoration activities; however, one goal of the mitigation was to create deeper pool areas. Sources of water to the site include surface water, as over 300 acres of surrounding land drain into the site, and groundwater, as several springs and seeps provide a connection to the existing wetland.

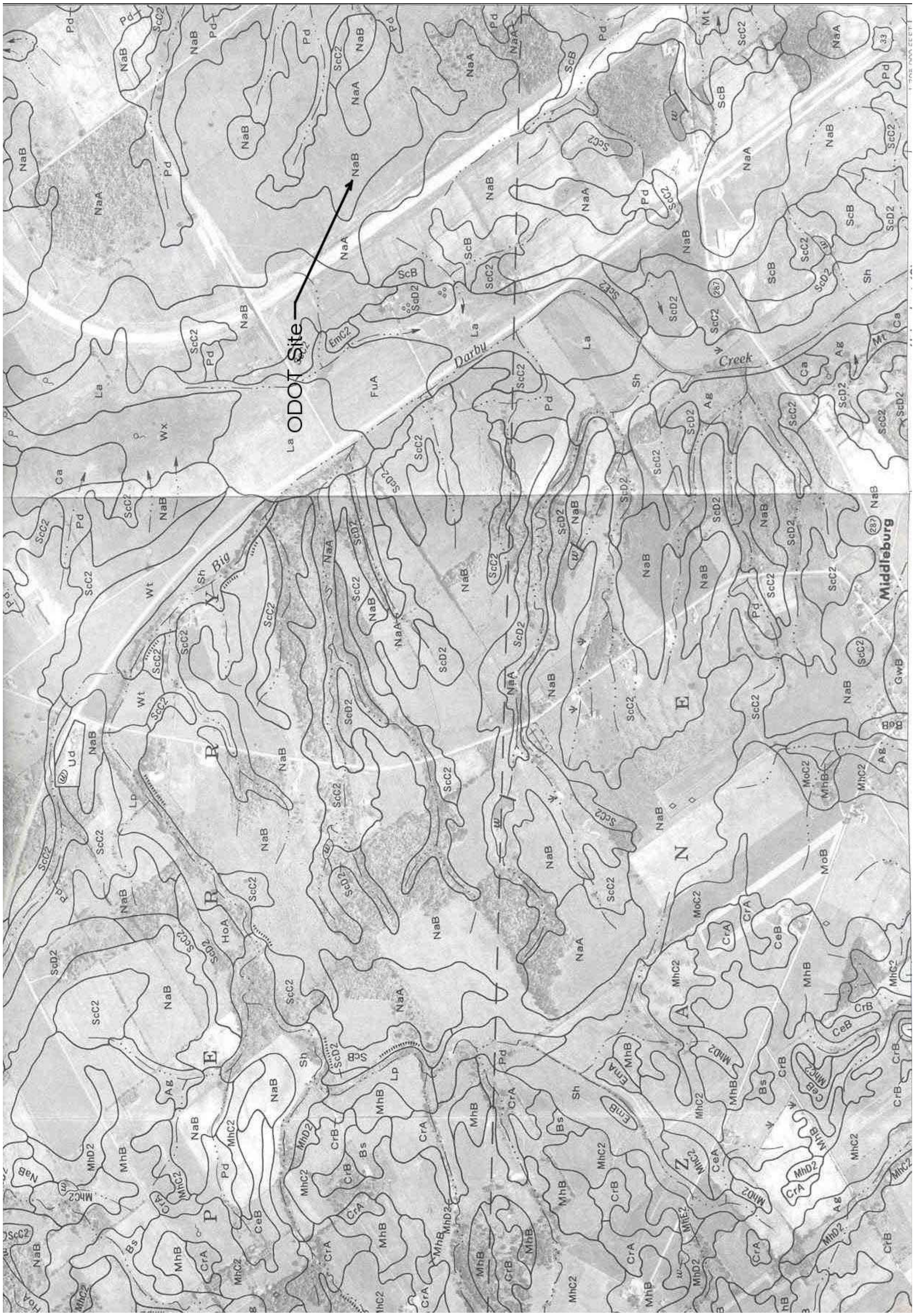
Plants were chosen based on their tolerance to varying inundation/saturation regimes. It was expected that different zones of plants would maintain themselves over the long-term, thereby providing a more diverse aquatic habitat for wildlife utilization. It was also expected that the prolific plants established in the existing wetland would serve as a seed source in the mitigated area. Native grasses and herbs, chosen based on their tolerance of rate of inundation/saturation and value to wildlife, were proposed for broadcasting following final grading of the site (ODOT, 1995).

Monitoring: Wetland construction was completed in 1997. During the year of 2001, the 4th year monitoring report was compiled and submitted to the Corps of Engineers. Ten plots had

Figure 7. Site location map of the ODOT site. This site is located in Perry Township, Union County, Ohio and on the East Liberty 7.5 minute USGS quadrangle.


ODOT Site
L I B E R T Y
A L L E N
Z A N E
East Liberty
Middleburg
Pottersburg
LOGAN CO
UNION CO

Figure 8. Soil types located at the Ohio Department of Transportation site as identified by the Soil Survey of Logan County (1975).


ODOT Site
Big
Darby
Creek
Middleburg
P E R R Y
Z A N E

been established to measure the success of vegetation. Dominant species identified included *Potomogeton foliosus*, *Agrostis alba*, *Eleocaris obtusa*, *Ludwigia palustris* and *Leersia oryzoides*. The presence of fish, amphibians, reptiles, mammals and birds was also identified and recognized. Over the monitoring period of 5 years, 42 species of birds and 6 species of salamanders had been identified within the wetlands (ODOT 2002).

Site 5 - Wetlands adjacent to an unnamed tributary of Blacklick Creek – New Albany, Franklin County, Ohio (sampling at year 6) (ODOT WCA site)

Site History: In association with the construction of a new road alignment, 24 wetlands, totaling 10.3 hectares, were impacted by the placement of fill material. Of these impacts, 2.7 hectares of forested wetlands would be impacted, while the remaining areas impacted consisted of emergent species. The highest level of impact would occur in four wetland areas, which were dominated by *Carex vulpinoidea*, *Juncus effusus*, *Juncus tenuis*, *Phalaris arundinacea*, *Scirpus atrovirens*, *Solidago gigantea*, *Cinna arundinacea*, *Impatiens capensis*, *Rhus radicans*, *Acer rubrum*, *Acer saccharinum*, *Quercus palustris*, *Ulmus americana*, *Carpinus caroliniana* and *Lindera benzoin*.

Mitigation: In order to compensate for losses associated with this project, over 8.1 hectares of wetlands would be restored at a site located along Foder Road in New Albany, Franklin County, Ohio (Figure 9). The majority of the site consisted of farm field, woodlands and an old field. An unnamed tributary of Sugar Creek, which flows into Big Walnut Creek, crosses the site. Most soils in the project area consist of Bennington, Cardington (both non-hydric with hydric inclusions) and Pewamo silt loams (hydric) (Figure 10). Two wetlands, totaling 2.83 acres were identified within the proposed mitigation site boundaries. Ditches had been dug previously to divert water flow off of the site and because much of the site consists of hydric soils, it was suspected additional wetlands had existed at this site prior to drainage activities. Dominant species were identified as *Typha angustifolia*, *Rosa palustris*, *Ulmus Americana*, *Salix nigra*, *Carex* sp., *Cornus racemosa*, *Acer sp*. and *Leersia oryzoides*.

Hydrology would be supplied by surface runoff from a watershed of approximately 170 acres and precipitation. Seasonally and regularly inundated or saturated areas would be created. The applicant proposed the creation of minimal open water to encourage high vegetation density. While a seed mix of *Agrostis alba*, *Leersia oryzoides* and *Panicum virgatum* was established during the first year, planting of herbaceous and woody species did not take place until the

Figure 9. Site location map of the ODOT WCA site. This site is located in Plain Township, Franklin County, Ohio and on the New Albany 7.5 minute USGS quadrangle.

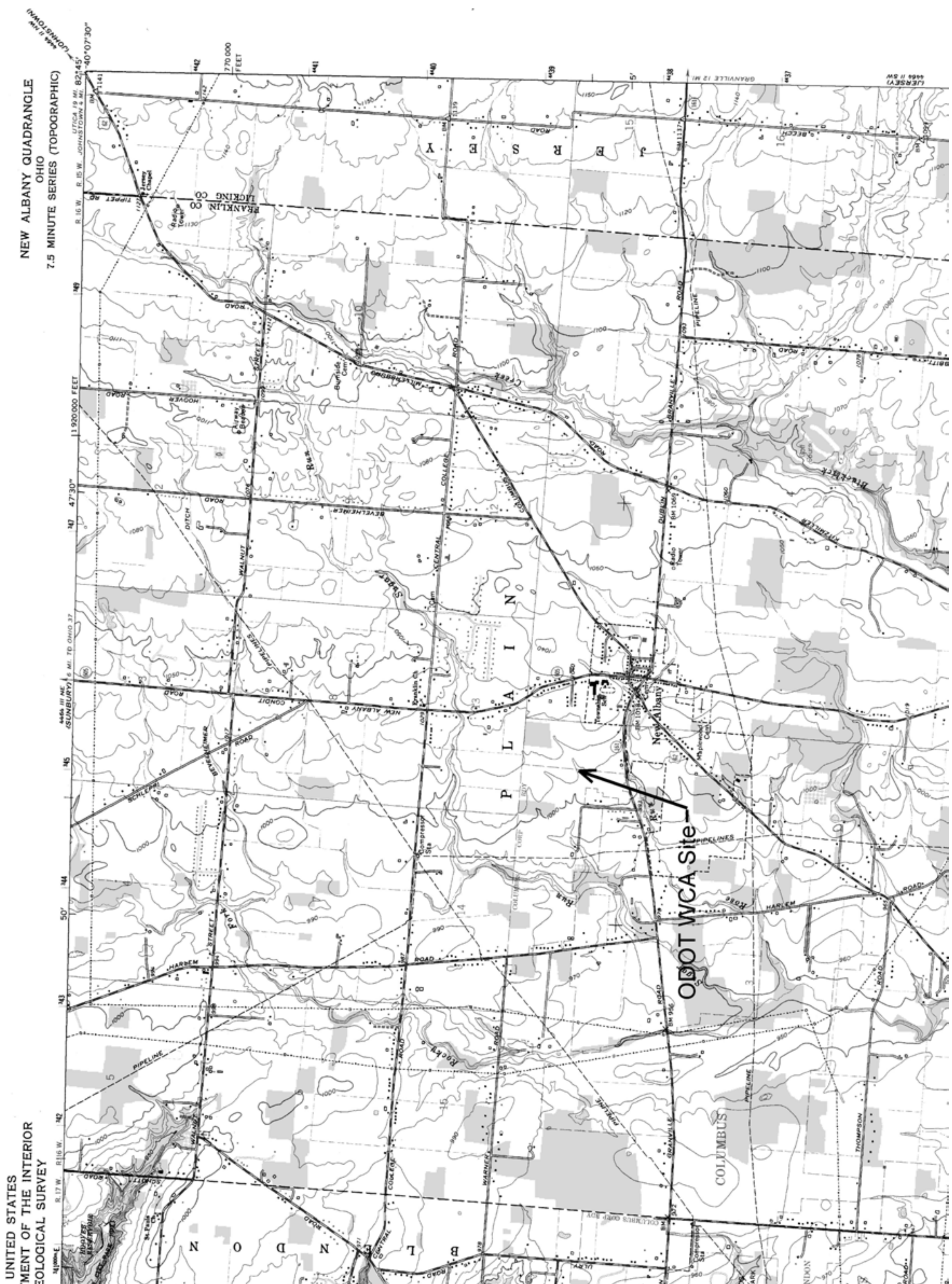
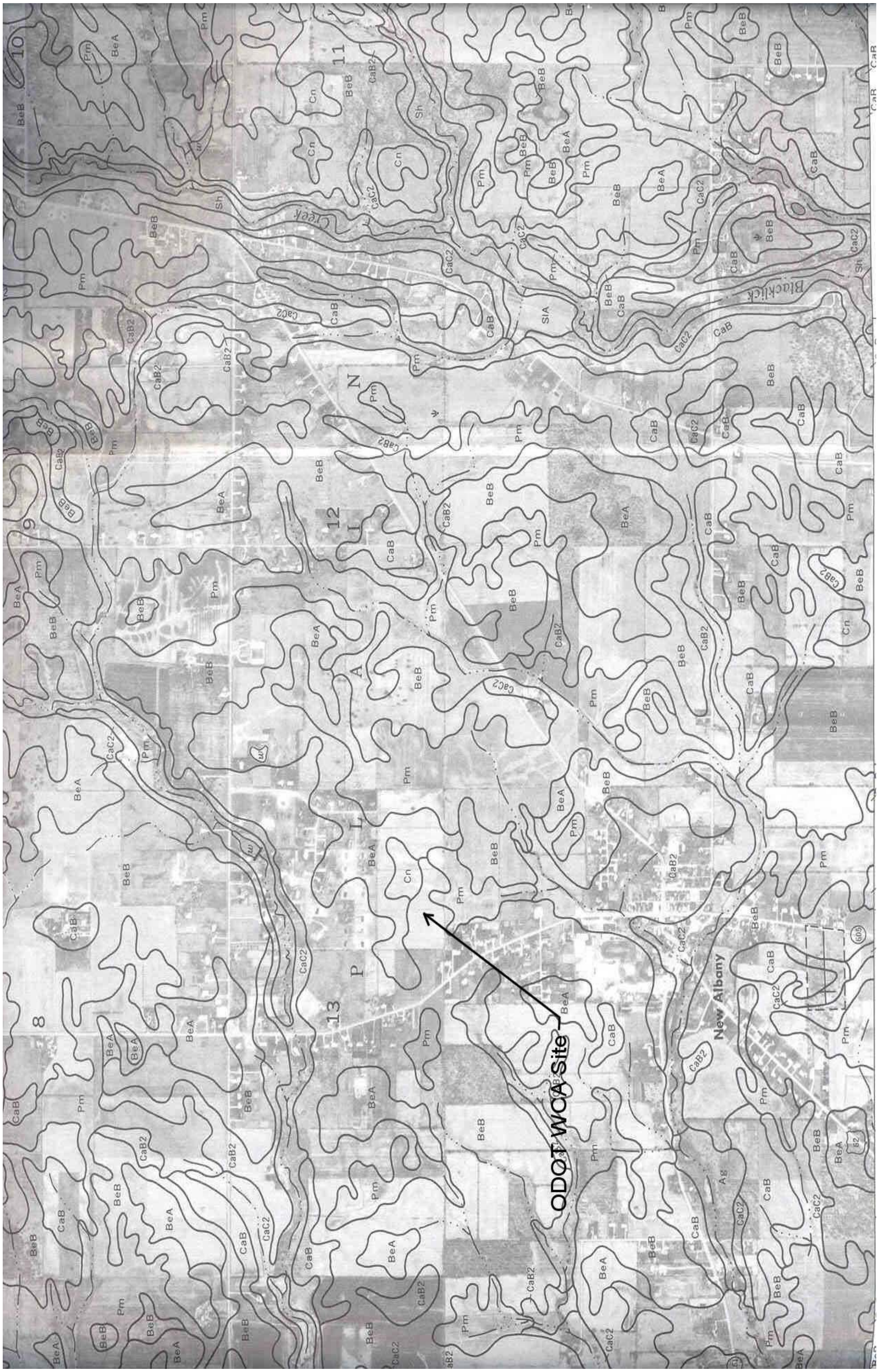

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
NEW ALBANY QUADRANGLE
OHIO
7.5 MINUTE SERIES (TOPOGRAPHIC)
ODOT WCA Site
New Albany
COLUMBUS

Figure 10. Soil types located at the ODOT Wildlife Conservation Area site as identified by the Soil Survey of Franklin County (1980).


ODOT WCA Site
New Albany
Blacklick
Creek

second year of the construction on-site. Anticipated wetland acreage totaled 8.1 hectares, to be located within a 16.2 hectare complex of wetlands, buffers and transition areas (URS Consultants, 1992).

Monitoring: Construction of the mitigated wetland system ended in 1996. Results of the 5th year monitoring report (URS), submitted to the COE in 2001 reflect the site's progression at that time. Only 5.5 hectares of wetland had been realized at this site, in contrast to the anticipated 8.1 hectares. To compensate for this shortage, additional mitigation acreage was developed at another site. Dominant plants, as identified along transects, included *Leersia oryzoides*, *Typha angustifolia*, *Echinochloa muricata* and *Bidens cernua*. Identification of dominants appeared to be completed by a general observation method, rather than establishment of transects and/or quadrats (URS, 2001).

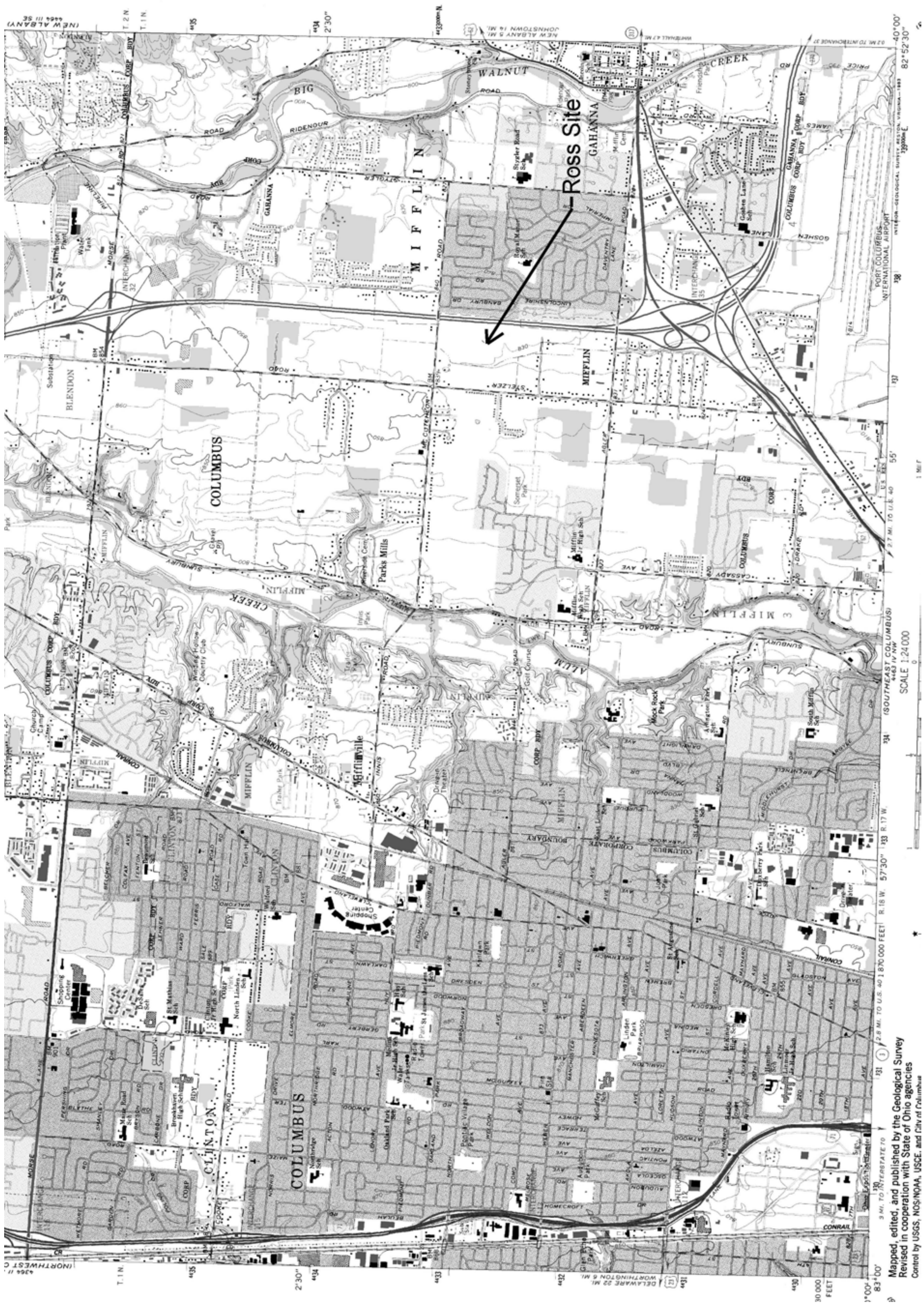
Site 6 - Wetlands adjacent to an unnamed tributary of Big Walnut Creek – Columbus, Franklin County, Ohio (sampling at year 11) (Ross site)

Site History: During the construction of a commercial development, 3.6 hectares of jurisdictional wetlands were filled along Stelzer Road in Columbus, Franklin County, Ohio. The hydric soil units of Pewamo and Condit comprised the entire wetland area. Dominant hydrophytic vegetation included *Juncus effusus, Asclepias incarnata, Aster nova-anglica*, *Ulmus Americana, Acer negundo, Acer rubrum, Typha latifolia, Quercus palustris* and *Fraxinus pennsylvanica*. Soils were identified as low chroma with mottles. Primary hydrology indicators included inundation and/or saturation within the upper 30 cm of soil.

Mitigation: Two wetland areas, totaling 6.1 hectares, were proposed to be restored on the east and west side of Codet Road in Columbus, Franklin County, Ohio (Figure 11). To maintain hydrology to both areas, these wetlands would be connected through a culvert installation beneath Codet Road. Only the wetland located west of Codet Road was investigated during this study. It was projected that this wetland would consist of 0.4 hectare of open water, 1.4 hectares of wet meadow and 2.5 hectares of forested wetlands.

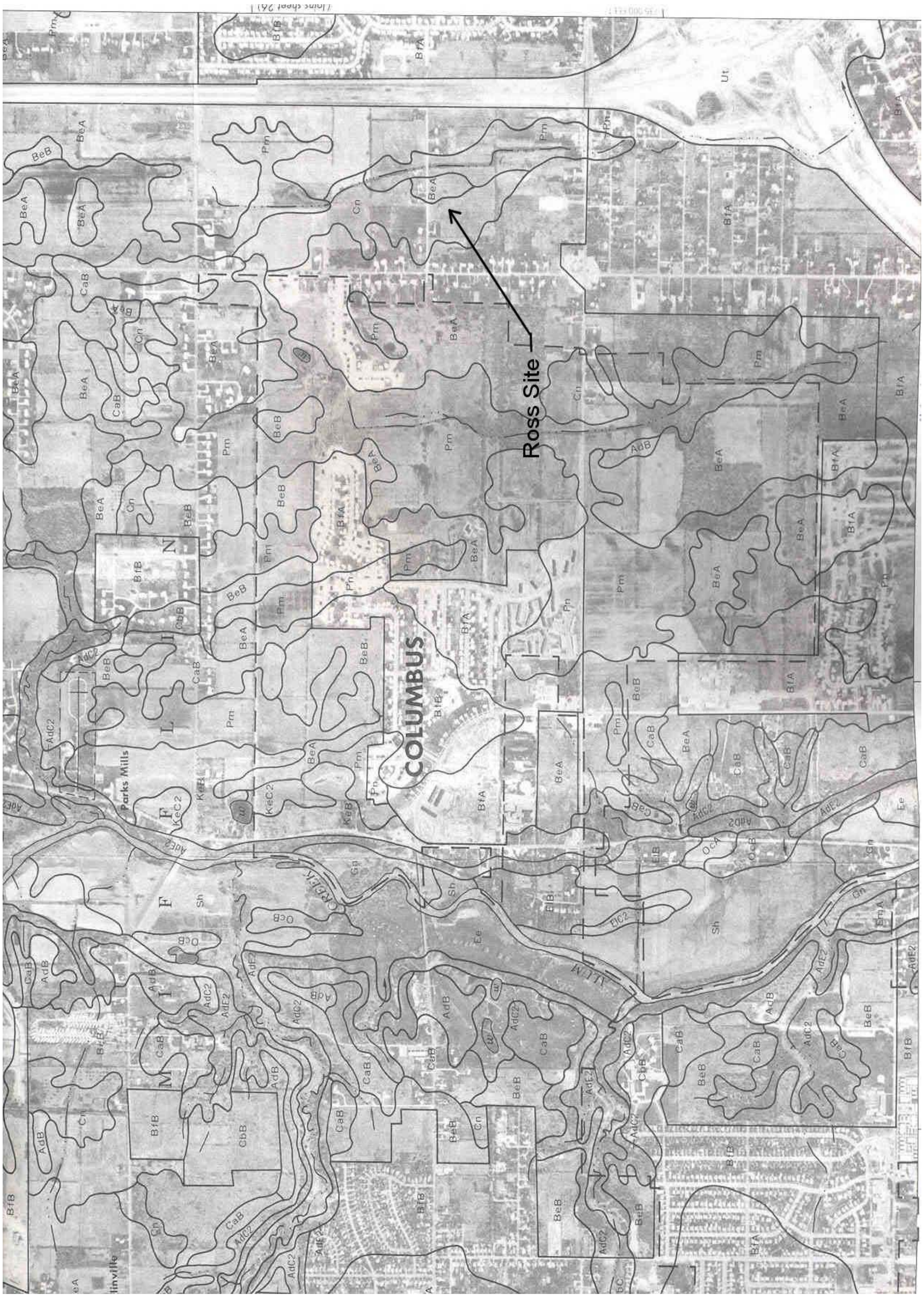
The restoration area consisted of Pewamo silty clay loam and Bennington silt loam, listed as hydric soils and non-hydric soils with hydric inclusions, respectively (Figure 12). Minor excavation and removal of dirt occurred in order to create changes in topography and to allow for a maximum water depth of 0.9 m. While a berm was not constructed on the wetland edges along Codet Road, all other wetland fringes were surrounded by a constructed berm. An existing

Figure 11. Site location map of the Ross site. This site is located in Mifflin, Franklin County, Ohio and on the Northeast Columbus 7.5 minute USGS quadrangle.



Ross Site
GAHANNA
MIFFLIN
COLUMBUS
CLINTON
Mifflinville
Parks Mills
BLENDON
PORT COLUMBUS INTERNATIONAL AIRPORT
(SOUTHEAST COLUMBUS)
SCALE 1:24 000
Mapped, edited, and published by the Geological Survey
Revised in cooperation with State of Ohio agencies
Control by USGS, NOS/NOAA, USCE, and City of Columbus

Figure 12. Soil types located at the Ross site as identified by the Soil Survey of Franklin County (1980).


Ross Site
COLUMBUS
Parks Mills

stream on-site would be included within the restoration area. This stream would flow through the wetland located west of Codet Road, beneath Codet Road and then through the second wetland restoration cell. Topsoil excavated from the upper 15-30 cm of the impacted wetland was removed and stockpiled. This soil was then placed on the surface of the mitigation area in order to serve as a seed source for the restoration area. Many wetland tree species including maples, dogwoods, ashes, cottonwoods, oaks and willows were proposed to be transported to the site as balled and burlapped trees. Seeds of various emergent wetland species were proposed to be broadcast over the wetland restoration area.

Monitoring: In 1996, the 5th year wetland monitoring report was submitted to the Army Corps of Engineers. This report documented the presence of vegetation along three transects in each wetland. Percent cover of species was not indicated; therefore, a determination could not be made concerning dominant vegetation present at the site during that year. Wildlife observation resulted in the identification of over 20 bird species within the wetland boundaries (Envirodyne Engineers, 1996).

CHAPTER IV
RESULTS AND DISCUSSION

VEGETATION DATA

Vegetation Data from each site as a whole

A total of 121 species representing 92 genera were identified as a result of vegetation analysis at the six study sites. The majority of species observed in this study were identified to species level, with the exception of three specimens that were identified to genus level only. These included species from the genera of *Vitis*, *Poa* and *Rubus*. All species identified in this study have been assigned a four-letter code (Appendix 1), the first two letters of which are the first two letters of the genus name and the second two of which are the first two letters of the specific epithet. In the case that two species would have the same code, the first and third letter of the specific epithet were used in assigning the last 2 letters of the code. This code will be used throughout this discussion when referring to a particular plant species. Of the total species identified in this study, 37 are designated as non-native and/or invasive species (Appendix 2 under 'C of C' heading). All sites contain a majority of native species (Figure 13). A checklist identifying the presence or absence of each species at each of the six study sites has been prepared (Appendix 3).

These 121 species were identified within the herbaceous emergent layer only of each study site. The only sites containing vegetation in the shrub stratum were the Honda, Medallion and New Albany sites. In each of these sites respectively, seven, nine and one species were identified in this layer, each of which were characterized by low percent cover. Because all sites in this study did not contain this parameter, it is not possible to compare and provide conclusions concerning the presence of shrubs in this study. Therefore, it is recognized these three sites do contain a developing shrub stratum and those species were identified (Table 3); however, shrub elements will not be further referred to in this study. Similarly, only the Honda and Medallion sites contained trees in the representative transects chosen for this study. At the Medallion site, trees greater than 4" diameter at breast height (dbh) were found in the OF plots adjacent to the mitigated wetlands. At the Honda site, trees greater than 4" dbh were present on-site many years prior to restoration of the area and are now currently within the boundaries of the mitigated wetland system. Trees at each site were identified (Table 4). Those most dominant at Honda

Figure 13. Number of native and non-native species identified at each of the six study sites.

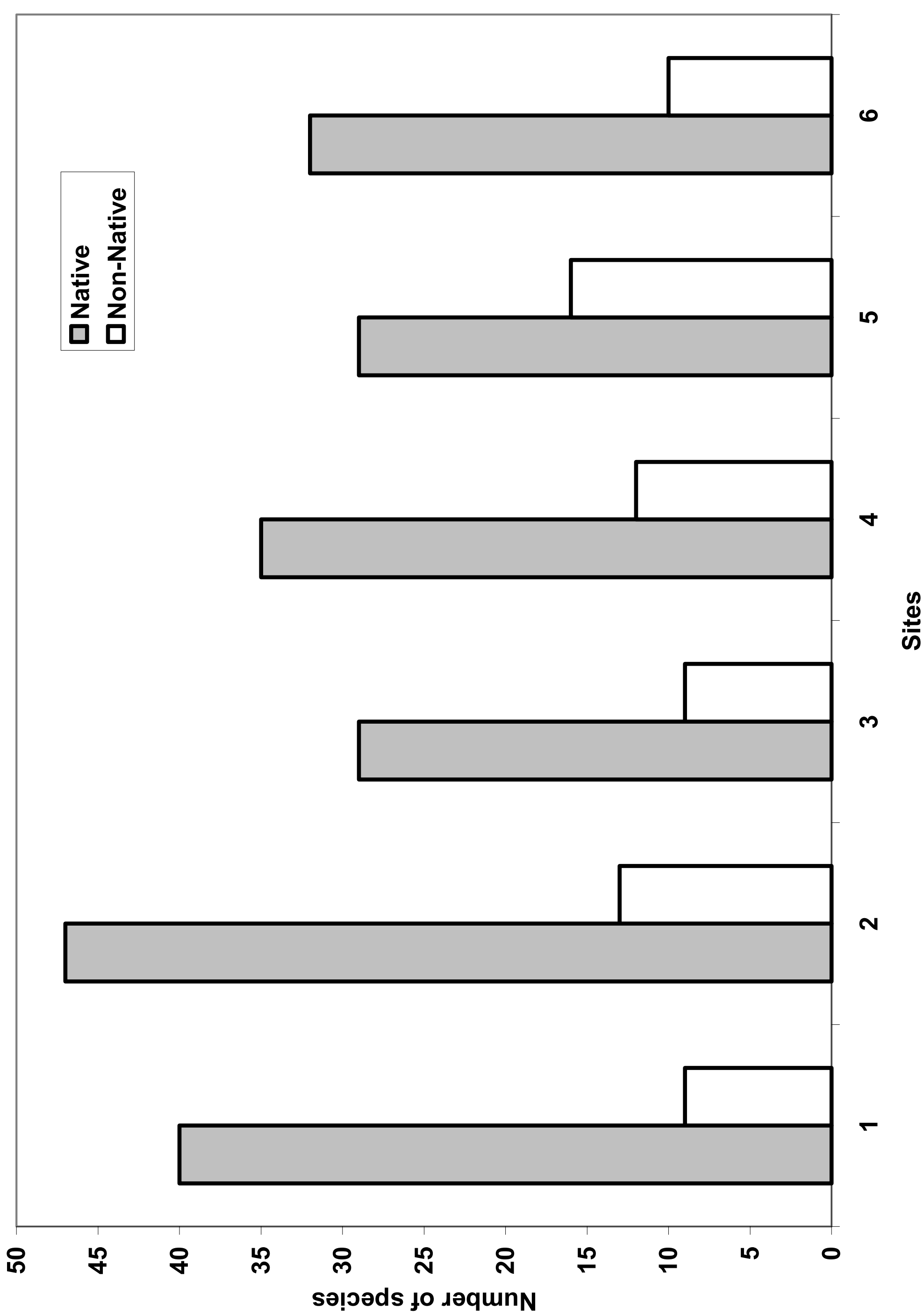

Native
Non-Native
Number of species
0
5
10
15
20
25
30
35
40
45
50
Sites
1
2
3
4
5
6

Table 3. List of all shrubs encountered in study transects at Honda, Medallion and New Albany sites. No shrubs were identifed in study transects at the remaining sites.

Site	Indicator	Common name	Code
Honda			
Cornus amomum	FACW	Silky dogwood	COAM
Crataegus viridis	FACW	Green Hawthorn	CRVI
Fraxinus pennsylvanica	FACW	Green Ash	FRPE
Populus deltoides	FAC	Eastern Cotton-wood	PODE
Quercus palustris	FACW	Pin Oak	QUPA
Salix caroliniana	OBL	Coastal-plain Willow	SACA
Salix nigra	FACW+	Black Willow	SANA
Medallion			
Acer saccharinum	FACW	Silver Maple	ACSA
Euonymus alatus	NI	Winged burning bush	EUAL
Fraxinus pennsylvanica	FACW	Green Ash	FRPE
Lindera benzoin	FACW-	Northern Spicebush	LIBE
Platanus occidentalis	FACW-	American Sycamore	PLOC
Populus deltoides	FAC	Eastern Cotton-wood	PODE
Quercus palustris	FACW	Pin Oak	QUPA
Rosa multiflora	FACU	Multiflora rose	ROMU
Viburnum prunifolium	FACU	Black-haw	VIPR
New Albany			
Salix nigra	FACW+	Black Willow	SANA

Table 4. List of all trees encountered at the Honda and Medallion sites. No trees were encountered in the study transects of the remaining sites.

Site	Indicator	Common Name	Code
Honda			
Acer negundo	FAC+	Box-elder	ACNE
Crataegus viridis	FACW	Green Hawthorn	CRVI
Fraxinus pennsylvanica	FACW	Green Ash	FRPE
Populus deltoides	FAC	Eastern Cotton-wood	PODE
Salix nigra	FACW+	Black Willow	SANI
Ulmus rubra	FAC	Slippery Elm	ULRU
Medallion			
Acer saccharinum	FACW	Silver Maple	ACSA
Fraxinus pennsylvanica	FACW	Green Ash	FRPE
Prunus serotina	FACU	Black Cherry	FACU
Quercus palustrus	FACW	Pin Oak	QUPA

were FRPE and PODE, trees with an indicator status of FACW and FAC, respectively. It was noted at the time of study that these trees were primarily located in the portion of the wetland affected by permanent inundation. However, neither of these trees can withstand permanent inundation and it was noted many appeared to be dying or dead. While this issue should be addressed from a monitoring and management standpoint, it will not be further discussed here, as this study is limited to the analysis of factors that may be compared from all wetland sites included in the study.

Of the species identified in this study, DACA, ECCR, ELOB, JUTE, LEOR, LEMI, POPR, SCVA, SOCA and TYLA, or 8.3 percent of the flora observed was observed at all of the six sites. Those species present in only one site and that corresponding site were: AGPA, CAGL, CRVI, FRVE, IRVI, LYNU, PRVU, TORA, VISP (Honda); ACRU, AGGR, CALP, EUAL, GATR, IMCA, JUAC, PIPU, POPE, SEFA, SPPO, VEHA, VIAC (Med); ERCA, QUPH, SANI, ULRU (New Albany); BENI, CYFE, LIBE, LIDU, MAMO, MESP, PODE, SEVI, XAST (ODOT); BRCO, CHLE, EPHI, HYMU, LUCA, PLRU, POSA, ROPS, UNGR (ODOT WCA); ELTE, ELVI, HEAU, JULE, POSP, RUSP, SAPA, SPPE, TYAN (Ross). Therefore, a total of 53 species, or 43.8 percent of all species encountered, were present at only one of the six study sites. This is not to say these species were absent entirely from the other five sites, but that each particular species was encountered in only one site as a result of choosing representative transects at each study site.

Indicator status refers to the likelihood that a particular plant species will occur in a particular habitat type. Designations for each species follow the USFWS National List of Plant Species that Occur in Wetlands. The indicator status for each species encountered is also presented in Appendix 1. Indicator status and associated preferred habitat as defined by Cowardin et al. (1979) is as follows: OBL, occur in wetlands 99 percent of the time; FACW, occur in wetlands 67-99 percent of the time; FAC, occur in wetlands 34-66 percent of the time; FACU, occur in wetlands one to 33 percent of the time; and UPL, occur in wetlands one percent of the time or less. A species assigned a designation of NI by the USFWS species is assumed to be an upland species and therefore found in wetlands less than 1 percent of the time. A (+) following either FAC or FACW indicates this species would be likely to be present in wetlands at percentages found at the higher end of the ranges described above.

When assessing vegetation at each site as a whole, in all but one of the sites (ODOT WCA), the number of OBL plants encountered at each site is greater than the number of species of any other indicator status (Figure 14). At ODOT WCA, the number of FACU plants constituted the greatest percentage of species richness at the site. However, this does not mean the SP and W zones were not dominated by FACW or wetter species, as in fact they were dominated by BICE, ELOB, TYLA, LEOR, LUPA and LEMA. Each of these species is FACW or OBL. Therefore, this data simply suggests the OF at the Ross site is more diverse than the OF zones at the other sites. Like Wilson and Mitsch's study of five wetland mitigation sites in Ohio (1996), the percentage of species comprising the groups of OBL, FACW or FAC were greater than 50 percent in all sites studied.

As a result of the collection of frequency and cover data for vegetation in the old field, seasonally inundated and permanently inundated zones of each site, the relative frequency and cover values for each species at each site as a whole were calculated. These values were used to calculate the importance values for each species (Appendix 2). These IV's were later used for multivariate analysis, which will be discussed in detail in Chapter V. The fifteen species with the highest importance values at each site are presented in decreasing order of importance in Tables 5-10. The sites of Honda, Medallion, New Albany, ODOT, ODOT WCA and Ross each are characterized, respectively, by one, eight, one, three, four and three dominant species that are not adapted to inundated/ saturated conditions (i.e. are designated by an indicator status of FAC-, FACU or NI). The Medallion site, with eight dominant non-hydrophytic species, presents the most significant concern. Of the 15 dominant species at each site, each site is characterized, respectively, by three, six, two, four, five and two non-native and/or invasive species. Of all sites, the Medallion site is most affected by non-native species, which represent nearly 40 percent of the overall importance value (Figure 15).

Vegetation data from zones (OF, SP and PW) at each site

Introduction

In order to assess the different vegetative communities in each of the three zones, the importance values for each species in each of the OF, SP and PW were calculated. In addition to providing information regarding the dominant species in each of the zones at each wetland, separating the data as a whole from each site into three sub-sets allowed comparison of

Figure 14. Number of obligate (OBL), facultative wet (FACW, FACW+, FACW-), facultative (FAC, FAC+, FAC-), facultative upland (FACU, FACU+, FACU-) and upland (NI) species identified at each of the six study sites.

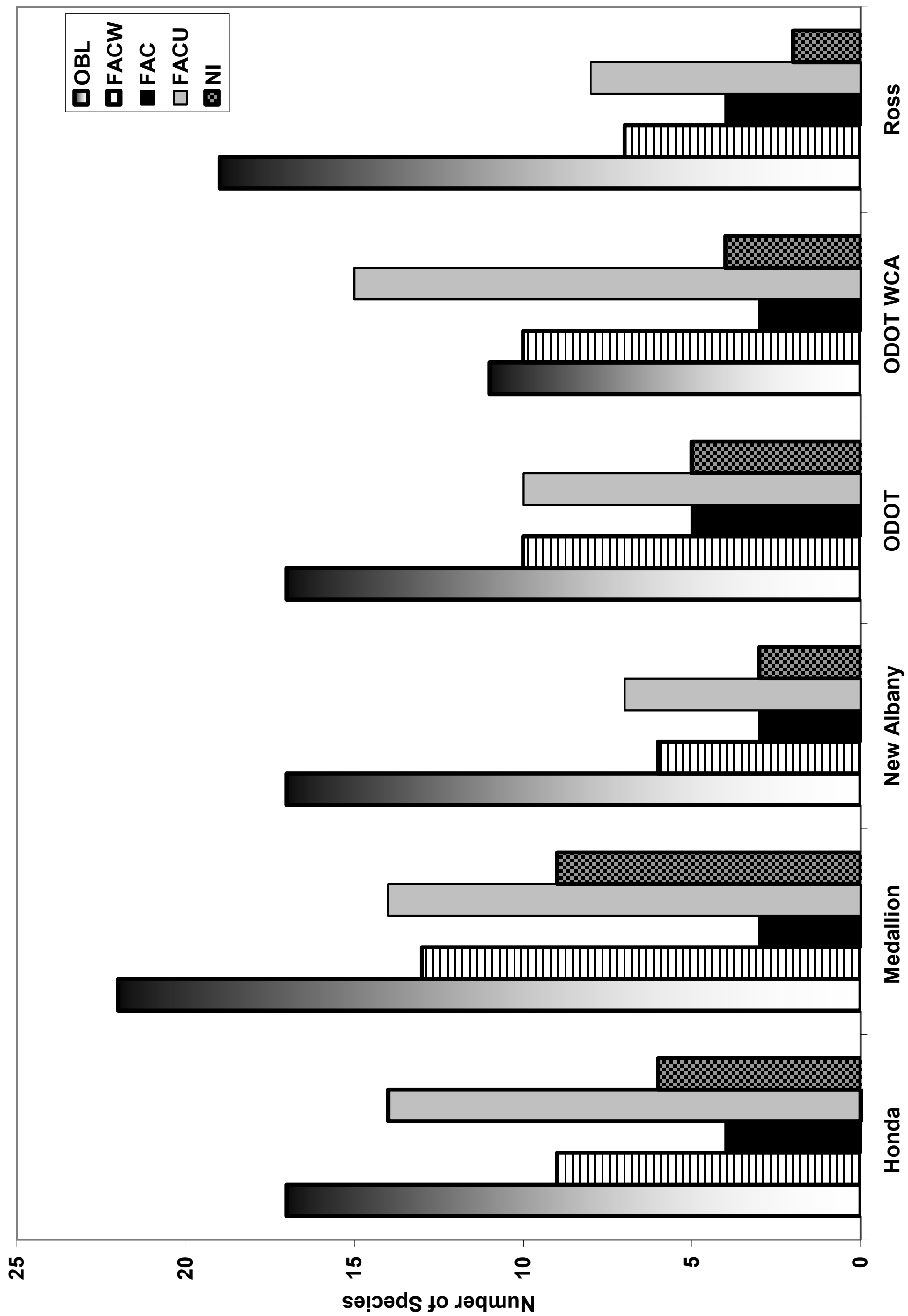
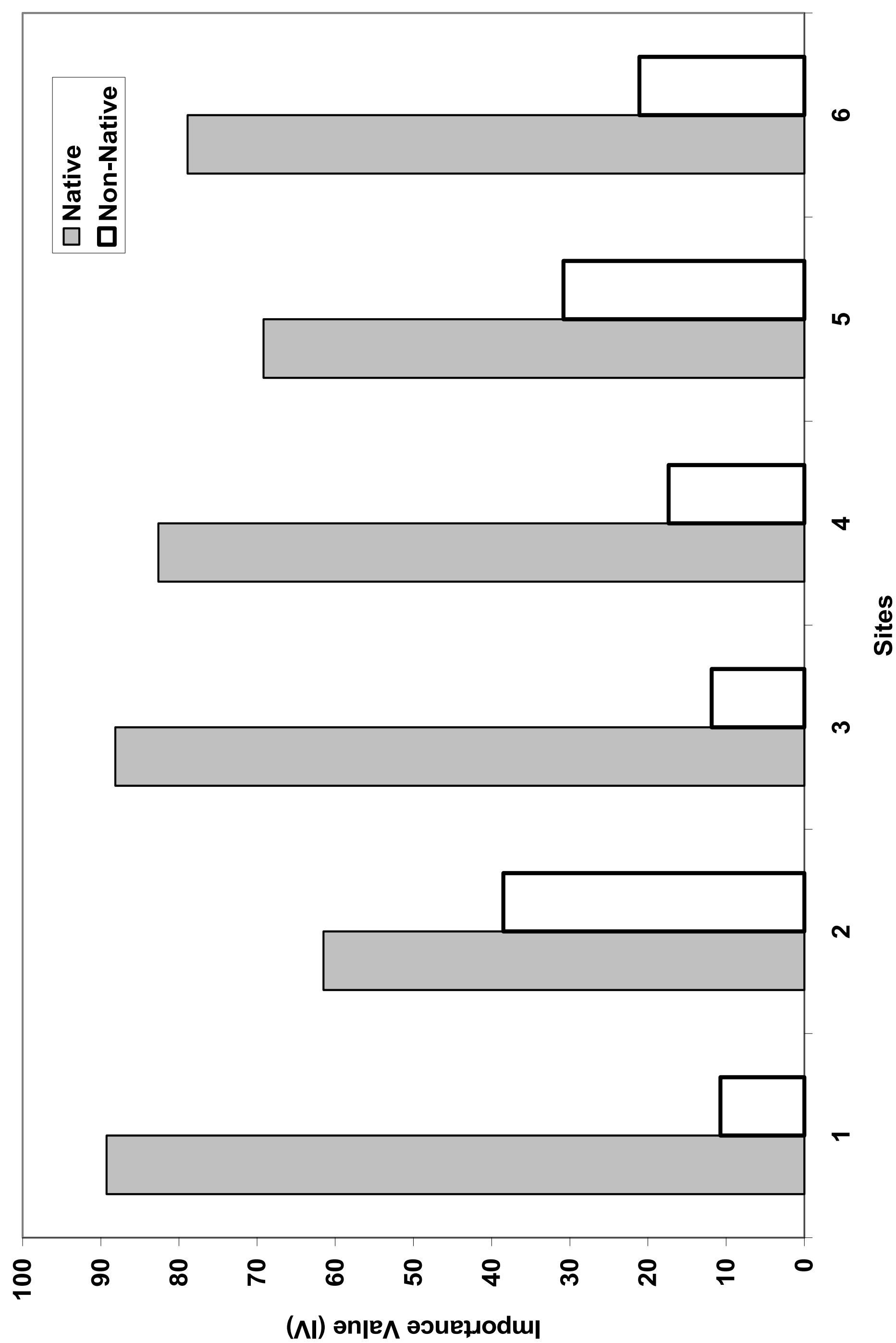

Number of Species
0
5
10
15
20
25
Honda
Medallion
New Albany
ODOT
ODOT WCA
Ross
OBL
FACW
FAC
FACU
NI

Figure 15. Percentage of importance value expressed by native and non-native species at each of the six study sites.



Native
Non-Native
Importance Value (IV)
0
10
20
30
40
50
60
70
80
90
100
Sites
1
2
3
4
5
6

Table 5. 15 dominant species at Honda site in decreasing order of importance.

Species	Code	Ind *	C of C †	IV ‡
Lemna minor	LEMI	OBL	3	24.41
Euthamia graminifolia	EUGR	FAC	2	6.29
Eleocharis obtusa	ELOB	OBL	1	5.70
Juncus effusus	JUEF	FACW+	1	5.02
Poa pratensis	POPR	FACU	*	5.00
Lysimachia nummularia	LYNU	OBL	*	4.28
Aster lateriflorus	ASLT	FACW-	2	3.93
Scirpus atrovirens	SCAT	OBL	1	3.55
Rosa palustris	ROPA	OBL	5	2.92
Fraxinus pennsylvanica	FRPE	FACW	3	2.34
Potamogeton foliosus	POFO	OBL	2	2.27
Dichanthelium clandestinum	DICL	FAC+	2	2.14
Lycopus americanus	LYAM	OBL	3	1.90
Carex frankii	CAFR	OBL	2	1.66
Crataegus viridis	CRVI	FACW	*	1.64

*, Indicator status as described by Reed et al. (1988); †, Coefficient of Conservatism as described by Andreas et al. (2004); ‡, Importance value

Table 6. 15 dominant species at Medallion site in decreasing order of importance.

Species	Code	Indicator	C of C	IV
Echinochloa crusgalli	ECCR	FACU	*	16.47
Poa pratensis	POPR	FACU	*	8.84
Eleocharis obtusa	ELOB	OBL	1	8.46
Leersia oryzoides	LEOR	OBL	1	4.59
Potamogeton nodosus	POND	OBL	3	4.08
Euthamia graminifolia	EUGR	FAC	2	3.40
Najas minor	NAMI	OBL	*	3.28
Daucus carota	DACA	NI	*	2.61
Cirsium vulgare	CIVU	FACU-	*	2.39
Juncus tenuis	JUTE	FAC-	1	2.24
Ludwigia palustris	LUPA	OBL	3	2.18
Aster laevis	ASLE	NI	6	2.17
Galium tinctorium	GATI	OBL	4	1.99
Solidago canadensis	SOCA	FACU	1	1.90
Setaria faberi	SEFA	NI	*	1.53

Table 7. 15 dominant species at New Albany site in decreasing order of importance.

Species	Code	Indicator	C of C *	IV**
Wolffia punctata	WOPU	OBL	6	26.10
Lemna minor	LEMI	OBL	3	13.04
Leersia oryzoides	LEOR	OBL	1	10.83
Ceratophyllum demersum	CEDE	OBL	2	8.45
Phalaris arundinacea	PHAR	FACW+	0	8.42
Potamogeton foliosus	POFO	OBL	3	4.31
Eleocharis obtusa	ELOB	OBL	1	3.24
Typha latifolia	TYLA	OBL	1	2.89
Carex cristatella	CACR	FACW	3	2.55
Salix nigra	SANI	FACW+	2	1.86
Polygonum amphibium	POAM	OBL	4	1.62
Scirpus validus	SCVA	OBL	2	1.54
Ludwigia palustris	LUPA	OBL	3	1.38
Alisma subcordatum	ALSU	OBL	2	1.15
Poa pratensis	POPR	FACU	*	0.94

Table 8. 15 dominant species at ODOT site in decreasing order of importance.

Species	Code	Indicator	C of C	IV
Echinochloa crusgalli	ECCR	FACU	*	8.17
Alisma subcordatum	ALSU	OBL	2	7.91
Eleocharis obtusa	ELOB	OBL	1	7.68
Ludwigia palustris	LUPA	OBL	3	6.95
Potamogeton nodosus	POND	OBL	3	5.82
Leersia oryzoides	LEOR	OBL	1	5.60
Aster lateriflorus	ASLT	FACW-	2	5.41
Bidens cernua	BICE	OBL	3	4.87
Ambrosia artemisiifolia	AMAR	FACU	0	4.69
Panicum virgatum	PAVI	FAC	4	3.68
Cyperus ferruginescens	CYFE	FACW	4	3.17
Scirpus validus	SCVA	OBL	2	3.05
Cyperus esculentas	CYES	FACW	0	3.01
Acalypha virginica	ACVI	FACU-	0	2.73
Bidens frondosa	BIFR	FACW	2	2.45

Table 9. 15 dominant species at ODOT WCA site in decreasing order of importance.

Species	Code	Indicator	C of C *	IV**
Typha latifolia	TYLA	OBL	1	6.44
Solidago flexicaulis	SOFL	FACU	5	3.00
Poa pratensis	POPR	FACU	*	3.35
Phalaris arundinaceae	PHAR	FACW+	0	8.46
Panicum virgatum	PAVI	FAC	4	2.07
Ludwigia palustris	LUPA	OBL	3	6.92
Leersia oryzoides	LEOR	OBL	1	9.25
Lemna minor	LEMI	OBL	3	3.66
Juncus tenuis	JUTE	FAC-	1	1.67
Euthamia graminifolia	EUGR	FAC	2	1.81
Eleocharis obtusa	ELOB	OBL	1	6.39
Echinochloa crusgalli	ECCR	FACU	*	1.80
Cirsium vulgare	CIVU	FACU-	*	4.18
Bidens cernua	BICE	OBL	3	14.16
Agrostis alba	AGAL	FACW	*	6.52

Table 10. 15 dominant species at Ross site in decreasing order of importance.

Species	Code	Indicator	C of C *	IV**
Carex vulpinoidea	CAVU	OBL	1	8.90
Ludwigia leptocarpa	LULE	OBL	*	8.08
Leersia oryzoides	LEOR	OBL	1	8.05
Typha latifolia	TYLA	OBL	1	6.58
Lemna minor	LEMI	OBL	3	5.05
Solidago canadensis	SOCA	FACU	1	5.02
Eleocharis tenuis	ELTE	FACW+	9	4.12
Helenium autumnale	HEAU	FACW+	4	4.12
Juncus effusus	JUEF	FACW+	1	4.09
Aster laevis	ASLE	NI	6	3.55
Typha angustifolia	TYAN	OBL	*	3.06
Geum vernum	GEVE	FACU	2	3.00
Aster lateriflorus	ASLT	FACW-	2	2.43
Elymus virginicus	ELVI	FACW-	3	2.41
Bidens frondosa	BIFR	FACW	2	2.22

vegetation data to environmental data collected from each of the three zones, which will be discussed later when all data is synthesized. The percent cover and frequency for each plant species encountered in each of the three zones at each of the six sites were used to obtain the IV of each species (Appendix 4).

Old field

The four dominant plant species in the old field at the Honda, Medallion, New Albany, ODOT, ODOT WCA and Ross sites were determined to be, respectively, POPR, SOCA, CIVU, ASLT; POPR, ECCR, EUGR, DACA; CACR, PHAR, POPR, ERST; PAVI, ASLE, AMAR, SOCA; POPR, AGAL, EUGR, SOCA; and SOCA, ASLE, GEVE, and CAVU (Table 11).

Of these 17 different species representing the dominant vegetation present in the OF at the study sites, five (ASLT, CACR, AGAL, PHAR, CAVU) have been assigned an indicator of FACW or FACW+. The dominant presence of CACR and PHAR at New Albany indicate the vegetation in the OF zone at this site is becoming hydrophytic. While the increase of wetland acreage over time is a positive attribute of this site, the presence of PHAR does present a concern, as this species is invasive, as will be further discussed below. The other dominant species present in the OF zones are FAC, FACU or NI and therefore are less likely to occur in wetlands. Therefore, because the OF represented an area just outside the wetland boundary and was not characterized by hydric soils or hydrology indicators, dominant vegetation predictably consisted primarily of species not adapted to growth in inundated conditions. The presence of those few species adapted to inundated conditions likely indicates these species are colonizers that rapidly are able to adapt to an area and could have become established because of close proximity of a seed source at the adjacent wetlands even though other wetland conditions do not prevail in the OF. In general, the overall quality of OF zones of these sites is low, as most of the sites, with the exception of ODOT and Ross are dominated by non-native and/or invasive species (i.e. POPR, CIVU, ECCR, DACA, PHAR, AMAR and AGAL).

Seasonally inundated

The four dominant plant species in the SP at the Honda, Medallion, New Albany, ODOT, ODOT WCA and Ross sites were determined to be (in decreasing order of importance): LEMI, EUGR, JUEF, ELOB; ECCR, ELOB, POPR, LEOR; WOPU, LEOR, LEMI, CEDE; ALSU, ECCR, ELOB, LUPA; BICE, PHAR, TYLA, LEOR; and LEOR, LULE, CAVU and JUEF (Table 12).

Table 11. Importance values (IV) for species found in the OF zones at each of the sites in this study. IV for each species is based on the sum of relative cover and relative frequency (values not shown.) Absolute cover and frequency values used for these calculations are shown in Appendix 4. An * by an IV indicates the four dominant species in the OF zone of each wetland.

Species	1	2	3	4	5	6
Acalypha virginica				3.56	1.91	
Acer rubrum		1.74				
Achillea millefolium	1.58	1.99			1.91	
Agrimonia parviflora	3.86					
Agrostis alba				3.56	10.98*	
Ambrosia artemisiifolia			4.4	9.26*		5.38
Apocynum cannabinum	2.23			3.56		
Aster laevis		3.99		18.14*		13.05*
Aster lateriflorus	5.17*	2.43				
Bidens frondosa				3.56	3.31	3.7
Calystegia sepium						3.37
Carex cristatella			13.92*			
Carex lupulina		2.43				
Carex tribuloides	5.11					
Carex vulpinoidea						7.38*
Chrysanthemum leucanthemum					2.26	
Cirsium vulgare	6.1*	4.85			5.92	4.1
Crataegus viridis	3.48					
Daucus carota	1.58	9.87*	8.24		2.96	1.68
Dichanthelium clandestinum		4.42				
Dichanthelium sphaerocarpon	3.48					
Echinochloa crusgalli		13.06*				
Elymus virginicus						6.69
Erigiron strigosus	4.13		10.72*	3.56		
Euthamia graminifolia		8.14*		4.63	8.72*	5.36
Festuca rubra	3.21				2.96	
Fraxinus pennsylvanica	5.11					
Galium triflorum		1.99				
Geum vernum	1.9					10.72*
Juncus tenuis	1.9	4.42	5.04		3.82	2.02
Leersia oryzoides			5.68			
Lemna minor	3.86					
Lespedeza cuneata					2.26	

Table 11. Continued.

Species	1	2	3	4	5	6
Lycopus americanus	2.23			4.63		1.68
Panicum virgatum				22.93*	6.97	3.35
Parthenocissus quinquefolia	1.9					
Phalaris arundinacea			12.08*			
Phleum pratense					5.06	
Plantago rugelii					2.61	
Poa pratensis	13.85*	23.09*	11.36*	5.69	12.38*	7.38
Potentilla norvegica	1.58				2.96	
Prunella vulgaris	1.58					
Quercus palustris	1.58	1.99			1.91	
Robinia pseudoacacia					3.66	
Rosa multiflora	1.9				2.96	2.68
Rosa palustris	1.9					
Rubus sp.						2.68
Rumex crispus			4.4	3.56	1.91	
Scirpus validus	3.21	1.74				
Setaria faberi		1.99				
Setaria glauca			3.25			
Solidago canadensis	9.02*	2.43	8.24	6.76*	8.02*	17.35*
Solidago flexicaulis			8.24			
Taraxacum officinale		1.99			2.26	
Toxicondendron radicans	4.78					
Trifolium pratense			4.4			
Trifolium repens		7.44		6.6	2.26	1.42
Vernonia glauca	1.9					
Vitis sp.	1.9					

Table 12. Importance values (IV) for species found in the SP zones at each of the sites in this study. IV for each species is based on the sum of relative cover and relative frequency (values not shown.) Absolute cover and frequency values used for these calculations are Appendix 4. An * by an IV indicates the four dominant species in the SP zones of each wetland.

Species	1	2	3	4	5	6
Acalypha virginica				2.84	0.5	
Acer negundo	0.45	0.43				
Acer rubrum		1				
Agrimonia gryposepala		0.62				
Agrimonia parviflora	1.13					
Agrostis alba	0.83	1.02			6.86	
Alisma subcordatum	0.98	1.04	1.67	9.21*		2.86
Ambrosia artemisiifolia				4.61		
Apocynum cannabinum		0.51				
Asclepias incarnata				0.65		0.99
Aster laevis		2.07				
Aster lateriflorus	3.78	0.51	0.57	6.29		3.85
Betula nigra				0.25		
Bidens cernua		1.13	1.2	5.67	17.44*	
Bidens frondosa	0.45	0.43		2.52		1.87
Botrychium dissectum		0.43				
Bromus commutatus					0.56	
Carex cristatella			2.07	0.7		
Carex franki	2.34	1.13				1.98
Carex glaucodea	0.45					
Carex lupulina		1.24				
Carex lurida	0.45	0.72				
Carex tribuloides	0.8	1.24			0.69	
Carex vulpinoidea	1.28		0.68	1.95	2.32	10.92*
Ceratophyllum demersum	0.84		10.8			
Cirsium vulgare	0.45	2.16			4.59	0.99
Cornus amomum	0.98	0.72		0.33	1.7	
Crataegus viridis	1.39					
Cyperus esculentus				3.5	0.5	2.33

Table 12. Continued.

Species	1	2	3	4	5	6
Cyperus ferruginescens				3.69		
Daucus carota		1.24		0.29	0.5	
Dichanthelium clandestinum	3.02	0.62				
Dichanthelium sphaerocarpon		1.45				
Echinochloa crusgalli	0.6	20.36*	0.52	9.16*	2.58	0.99
Eleocharis obtusa	5.29*	9.81*	3.79	8.93*	8.17	
Eleocharis tenuis						4.56
Elymus virginicus						0.99
Epilobium hirsutum					0.88	
Eragrostis capillaris			0.73			
Euonymus alatus		0.45				
Euthamia graminifolia	6.94*	2.77		0.33	0.69	
Festuca rubra	1.06				0.69	
Fraxinus pennsylvanica	0.98	0.43	0.57			
Galium tinctorium		2.82				0.87
Galium triflorum		1.43				
Helenium autumnale						6.48
Hypericum mutilum					0.5	
Impatiens capensis		2.11				
Iris virginica	0.83					
Juncus acuminatus		1.24				
Juncus effusus	6.27*	1.02	0.57		0.63	6.54*
Juncus tenuis		2.05		0.33	1.38	0.87
Leersia oryzoides	2.19	5.08*	14.54*	6.51	8.42*	12.79*
Lemna minor	30.51*		12.64*	0.25	1.82	4.04
Lindera benzoin				0.33		
Lindernia dubia				0.77		
Ludwigia leptocarpa						12.73*
Ludwigia palustris		1.87	1.98	8.08*	4.34	3.15
Lycopus americanus	2.11	0.51				
Lysimachia nummularia	5.22					
Malva moschata				0.25		
Mentha spicata				0.43		

Table 12. Continued.

Species	1	2	3	4	5	6
Najas minor		0.72		0.33		
Panicum virgatum				2.23	1.38	
Parthenocissus quinquifolia		0.51				
Penthorum sedoides			0.57	0.33		2.22
Phalaris arundinacea		0.62	9.23*		9.82*	
Phleum pratense		1.25			0.69	
Pilea pumila		1.66				
Poa pratensis	3.48	6.9*		0.94	2.07	
Polygonum amphibium			2.35		0.94	
Polygonum hydropiperoides		0.47		2.22	1.63	3.61
Polygonum persicaria		0.62				
Polygonum sagittatum					0.69	
Populus deltoides				0.43		
Portulaca oleracea						0.99
Potamogeton foliosus	2.56	0.62	3.07			
Potamogeton nodosus	0.53	2.29	1.29	4.97		
Potentilla norvegica				0.33		
Rosa multiflora	3.55					
Rosa palustris						0.99
Rumex crispus				1.52	1	
Sagittaria latifolia		1.46	0.78			
Salix nigra			1.86			
Samolus parviflorus						0.87
Scirpus atrovirens	5	0.51	0.57			
Scirpus validus		0.72	2.17	3.55	1.45	
Setaria faberi		1.66				
Setaria glauca		1.88		1.47		
Setaria viridis				0.81		
Solidago canadensis		2.1		0.33	0.5	0.99
Solidago flexicaulis					4.28	
Spartina pectinata						1.23
Trifolium pratense		0.62				
Trifolium repens				0.29		

Table 12. Continued.

Species	1	2	3	4	5	6
Typha angustifolia						3.1
Typha latifolia	1.51	1.24	2.8	1.23	9.19*	6.19*
Ulmus rubra			0.68			
Unknown grass					0.56	
Verbena hastata		0.62				
Vernonia glauca	1.06	0.72				
Viburnum acerifolium		0.51				
Vitis sp.	0.68					
Wolffia punctata		0.62	22.29*			
Xanthium strumarium				1.09		

Of the 16 dominant species present in the SP zones of the study sites, three (EUGR, ECCR and POPR) are designated as either FAC or FACU. The remaining species are either FACW+ or OBL. Two of these three species, ECCR and POPR, were both identified at the Medallion site and are FACU. The above IV's correspond to percent cover values of 33 and 10 percent for ECCR and POPR, respectively, at the Medallion site. These cover values, along with the cover values of other FACU or UPL species at the Medallion site exceed 50 percent and therefore, the seasonally inundated zone of this site does not currently contain a dominant percent cover of hydrophytic species. If the site was still in the monitoring period, it would be necessary for the responsible party to take corrective actions to ensure dominant hydrophytes are present in the area that should contain wetlands. The presence of EUGR as the second most dominant species in the SP at the Honda site and the presence of ECCR as the second most dominant species in the SP at the ODOT site is not significant enough to result in a greater aerial cover of upland species and therefore the SP zone at these sites are dominated by hydrophytic species. The presence of all FACW and OBL dominant plants at each of the remaining four sites is positive and indicates these sites contain a sufficient amount of hydrophytic species to fulfill the wetland vegetation parameter mandated by the COE's delineation manual. In general, the quality of the SP zones at each of these sites is higher than that observed in the OF zones, as most sites contain few to no non-native and/or invasive species as dominants. Medallion contains two (POPR and ECCR), while ODOT, ODOT WCA and Ross each contain one non-native species as a dominant (ECCR, PHAR and LULE, respectively.)

Permanently inundated

The four dominant plant species in the PW at the Honda, Medallion, New Albany, ODOT, ODOT WCA and Ross sites were determined to be (in decreasing order of importance): LEMI, ELOB, POND, FRPE; NAMI, POND, ELOB, LEMI; WOPU, LEMI, POFO, PHAR; LEMI, POND, NAMI, POFO; LUPA, LEOR, LEMI, BICE; and LEMI, TYLA, ELOB, and TYAN (Table 13).

Of the thirteen dominant species identified in the PW of each of the sites, the majority are designated as OBL, and therefore are adapted to growth in inundated and/or saturated conditions and will be found in wetlands 99 percent of the time. Only FRPE and PHAR are designated as FACW or FACW+ and less likely to be found in permanently inundated conditions. Notice the diversity among sites is less, as a total of only 13 dominant species were identified among all

Table 13. Importance values (IV) for species found in the PW zones at each of the sites in this study. IV for each species is based on the sum of relative cover and relative frequency. (Values not shown.) Absolute cover and frequency values used for these calculations are shown in Appendix 4. An * by an IV indicates the four dominant species in the PW zones of each wetland.

Species	1	2	3	4	5	6
Alisma subcordatum	3.79	5.38				
Aster lateriflorus	3.79					
Bidens cernua					14.75*	
Ceratophyllum demersum	8.25		3.72			
Echinochloa crusgalli				5.1		7.66
Eleocharis obtusa	18.92*	13.39*	2.72		5	12.33*
Euthamia graminifolia	3.79					
Fraxinus pennsylvanica	8.46*		2.2			
Juncus effusus	6.46					
Leersia oryzoides		8.13			25.27*	
Lemna minor	24.5*	10.21*	19.79*	36.73*	16.19*	26.9*
Lysimachia nummularia	6.46					
Ludwigia palustris		7.46			27.23*	
Najas minor		22.18*		21.44*		
Phalaris arundinacea			5.09*		11.55	
Potamogeton foliosus	5.79	3.73	10.18*	10.1*		
Potamogeton nodosus	9.79*	20.42*		26.63*		
Quercus phellos			1.86			
Salix nigra			2.55			
Scirpus validus						10.78
Spirodela polyrhiza		3.18				
Typha angustifolia						10.78*
Typha latifolia			4.26			26.22*
Wolffia punctata		5.93	47.63*			5.32

sites, in comparison to 16 and 17 in the zones described above. This is to be expected, as fewer plant species are adapted to live in permanently inundated areas and many species depend on a period of drawdown to release seeds from the seed bank (Pierce 1994). It is positive, though, that the permanent standing water zones do contain hydrophytic vegetation for a least of distance of at least 10 meters. Most dominant species in the PW zones of each site are native, with the exception of the presence of PHAR at New Albany and TYAN at the Ross site.

Presence of invasive species

Invasive plant species are those that have been identified as non-native species that may threaten natural areas. More than 700 non-native species have been recognized in Ohio, and of that number, 65 species have been recognized as those that threaten natural areas. In 2000, the Ohio Department of Natural Resources (ODNR) and The Nature Conservancy (TNC) developed three categories of invasive species based on their likelihood to threaten natural areas. These categories are targeted species, well-established species and watch list species. All sites in this study contained at least two and no more than four of the species identified by the ODNR and TNC as non-native invasives (Table 14).

Targeted species are those species with a state-wide distribution that have been recognized as the most likely to invade and threaten natural areas. These are the most difficult to control. Of the 13 species identified by ODNR and TNC as targeted species, two species, ROMU and PHAR, were identified in this study. ROMU was identified in the OF and SP of the Honda site, in the OF at the ODOT WCA site and in the OF at the Ross site. Importance values ranged from 1.9 to 3.55 (Table 14). While these may appear low, because this species has been recognized as a targeted species and one that threatens natural areas, it would be recommended this species is removed from these sites.

PHAR was also present in three of the study sites, as it was identified in the SP of Medallion, all three study zones of New Albany and the SP and PW zones of ODOT WCA. IV of this species at Medallion was low (0.62) and therefore may not constitute a threat. However, the IV's of this species at the other study areas ranged from 5.09 to 12.08. This is a significant concern. Studies have documented failure of a mitigation site is many times due to invasion by non-native species that threaten the natural area (Kellogg and Bridgham 2002). Because these sites are relatively young, if this species is not controlled and eradicated soon, it has the potential to threaten other native species present at those sites. PHAR is documented as a species that

Table 14. Importance values (IV) for species recognized as invasive at each of the sites in each of the three zones of OF, SP and PW

Site and zone	ROMU	PHAR	LYNU	NAMI	DACA	EPHI	EUAL	TYAN
Honda OF	1.9				1.58			
Honda SP	3.55		5.22					
Honda PW			6.46					
Medallion OF					9.87			
Medallion SP		0.62		0.72	1.24		0.45	
Medallion PW				22.18				
New Albany OF		12.08			8.24			
New Albany SP		9.23						
New Albany PW		5.09						
ODOT OF								
ODOT SP				0.33	0.29			
ODOT PW				21.44				
WCA OF	2.96				2.96			
WCA SP		9.82			0.5	0.88		
WCA PW		11.55						
Ross OF	2.68				1.68			
Ross SP								3.1
Ross PW								10.78

spreads vegetatively, rapidly allocates resources to new growth, and is able to increase its productivity in areas affected by high rates of sedimentation and/or nutrient levels (Green and Galatowitsch 2001). A study completed by Zedler and Werner in 2000 and documented by Maurer et al. (2003) concluded in areas dominated by PHAR, a PHAR stand will support only one-ninth the number of species present in other stands dominated by such invasive species as *Typha* spp. (i.e. a PHAR stand contained 3 different species while a *Typha* stand contained 28 species). The Maurer et al. study documented PHAR is most likely to spread in an herbaceous wetland with little canopy cover, as it requires high levels of light to experience high germination levels. Therefore, mitigation sites in their early years because they are composed primarily of emergent species are particularly subject to the rapid invasion of this species. While the initial dispersal may be uncontrollable, the germination and vegetative growth of this species must be controlled in order to ensure the success of native species in wetlands. Any presence of this species should be quickly identified and eradicated to inhibit its spread (Maurer et al. 2003). In general, an *r*-selected species, such as PHAR, that quickly colonizes an area following a disturbance, in the context of creation or restoration activities, may inhibit later successional species that are important to the overall functioning ability of the wetland (Heaven et al. 2003).

The ODNR and TNC have identified 38 species as well-established invasive plants that have a statewide or regional distribution in Ohio and pose moderate to serious threats to natural areas in Ohio. Of these 38 species recognized as well-established, five of those species were identified in at least one of the study sites. These are LYNU, NAMI, DACA, EPHI and EUAL. Of particular concern is the presence of NAMI in the PW of the Medallion site and the PW of the ODOT site, with IV's of 22.18 and 21.44, respectively (Table 14). As described above in reference to the presence of PHAR, it would be recommended NAMI is removed from these sites before it threatens native species present at these sites.

Fourteen species have been identified as watch list species. These species have been identified as invasives that threaten natural areas in states neighboring Ohio. While their current distribution in Ohio is limited, their presence should be monitored. None of these species were identified in this study.

There is some controversy concerning whether any presence of an invasive species is acceptable at mitigation sites. The Ohio Environmental Protection Agency typically will release a mitigation site from further monitoring if no more than five percent aerial cover of the species is present at the final year of monitoring (personal communication, Laura Fay of OEPA). This is also typical practice at the COE. However, the US Fish and Wildlife Service strongly supports that a mitigated wetland should not be released from monitoring unless there are no invasive species present. They indicate invasive species are typically very aggressive and display exponential growth habits after they are established. For example, if in the fifth and final year of monitoring, a wetland contains five percent of an invasive plant, this species will very likely begin to grow at a fast rate, overtaking an area and inhibiting the growth of those valuable native species present in the wetland (Personal communication, Sarena Selbo, USFWS of Reynoldsburg, Ohio). If this happens after monitoring has ended and the responsible party has been released from further obligations, the regulatory agency could not require any corrective actions at that time.

Presence of species identified as valuable to wildlife

While this study did not include an assessment of wildlife utilizing the mitigated wetland systems, it is important to note those species that were present that may serve the important functions of providing a food source and/or habitat to wildlife. While it is recognized some species are more useful in providing a substantial food source to wildlife (personal communication, Sarena Selbo of USFWS), recent research has given little attention to this topic. Martin et al. (1951) detailed those plant species from several different ecosystem types that are recognized as important food sources to wildlife. Of the aquatic species studied, they found the following genera, also identified in this study, were important in varying degrees to the diets of many different birds and small mammals in Ohio (identified by Martin et al. as the northeastern region of the US): *Typha*, *Potamogeton*, *Najas*, *Sagittaria*, *Spartina*, *Echinochloa*, *Cyperus*, *Scirpus*, *Eleocharis*, *Lemna*, *Wolffia* and *Polygonum* (Table 15). Only one hydrophytic species, LEOR, identified in this study was identified by Martin et al. to species level and recognized as important in the diets of several birds in the northeastern region of the US. The Medallion site contained 10 of the genera identified by Martin et al. as good food sources. The other sites contained between six and nine of the identified genera (Table 16). Of those genera identified by Martin, Knight (1997) specifically identified CYES, JUEF, LEMI, POND, SALA, SCVA and TYLA as important to many birds and/or small mammals. In addition, Knight identified an additional species, CEDE, whose genus had not been reported by Martin as important to wildlife. Each of these species were found in several of the sites in this study. More recently, Brown

Table 15. Wetland plant genera used by birds and/or small mammals (Martin et al. 1951).

Plant genus	Parts used	Birds and/or small mammals using specific plant	Importance in diet ‡
Typha	Roots, Leaves	Muskrat	****
Potamogeton	Seeds, plants	Mallard	***
		Pintail	***
		Wooduck	***
		Ring-Necked	****
		Greater scaup	***
		Lesser scaup	***
		Blue-winged teal	**
		Coot	***
		American goldeneye	**
Najas	Leaves, Seeds	Coot	***
		Pintail	*
		Ring-Necked	*
		Greater scaup	**
		Lesser scaup	****
		Blue-winged teal	**
		Green-winged teal	*
Sagittaria	Seeds, Tubers	Mallard	*
		Lesser scaup	*
		Muskrat	**
		Porcupine	*
Spartina	Roots, Seeds	Green-winged teal	+
Leersia oryzoides	Seeds, roots	Mallard	**
		Pintail	+
		Ring-Necked	*
		Lesser scaup	+
		Blue-winged teal	*
		Green-winged teal	*
	Seeds	Rail, Sora	*
		Sparrow	*
Echinochloa	Seeds	Pintail	**
		Mallard	**
		Ring-Necked	+
		Blue-winged teal	+
		Green-winged teal	**
		Rail, Sora	*
Cyperus	Seeds, tubers	Green-winged teal	**
		Woodcock	+
		Sparrow	*
Scirpus	Seeds	Coot	***
		Mallard	+
		Pintail	***
		Ring-Necked	*
		Greater scaup	+

Table 15. Continued.

Plant genus	Parts used	Birds and/or small mammals using specific plant	Importance in diet ‡
		Lesser scaup	*
		Blue-winged teal	**
		Green-winged teal	***
	Seeds, roots	Sora	**
		Virginia rail	*
		Bunting	+
		Song sparrow	+
	Roots, stems	Muskrat	***
		Meadow mouse	+
Eleocharis	Seeds, tubers	Coot	+
		Pintail	*
		Blue-winged teal	*
		Green-winged teal	*
	Seeds	Sora	*
		Virginia Rail	*
	Plant	Muskrat	+
Lemna, Wolffia	Plant	Coot	*
		Mallard	+
		Blue-winged teal	***
		Wood duck	*
		Rail, Sora	+
Polygonum	Seeds	Coot	+
		American goldeneye	+
		Mallard	***
		Pintail	***
		Ring-Necked	**
		Lesser scaup	+
		Blue-winged teal	*
		Wood duck	**
		Red-wing blackbird	**
		Cardinal	***
		Cowbird	+
		Rose-breasted grosbeak	*
		Meadowlark	+
		Song sparrow	***
		White-throated sparrow	***
		Towhee	**

‡, + = ½ - 2% of diet; * = 2 - 5% of diet; ** = 5 - 10% of diet; *** = 10 - 25% of diet; **** = 25 - 50% of diet

Table 16. Genera and species identifed by Martin et al. (1951) as important food sources to wildlife and their presence or absence at sites in this study. An 'X' represents presence.

Genera and species	Honda	Medallion	New Al	ODOT	ODOTWCA	Ross
Potamogeton	X	X	X	X		
Najas		X		X		
Sagittaria		X	X			
Spartina						X
Leersia oryzoides	X	X	X	X	X	X
Echinochloa	X	X	X	X	X	X
Cyperus				X	X	X
Scirpus	X	X	X	X	X	X
Eleocharis	X	X	X	X	X	X
Lemna	X	X	X	X	X	X
Wolffia		X	X			X
Polygonum		X	X	X	X	X

(1999) has studied avifaunal food value supplied by mitigated wetland systems. This study reported the presence of 15 different species recognized by Martin et al. and Payne (1992) as important to wildlife. Cover of these species was reported to be relatively high.

In addition to presence of specific species, it is important to note it has been documented wetlands that provide high quality waterfowl habitat are those characterized by areas of open water with areas of vegetation and high vegetation density (Confer and Niering 1992). Wetlands characterized by a monotypic stand of one particular species will provide little value to wildlife, as most species require diverse habitat types for food and cover needs (Payne 1992). The availability of seeds and foliage in the fall and winter is particularly important to migratory waterfowl. Seed production is enhanced when shallow water areas are present and allow species of *Polygonum*, *Eleocharis* and other edge plants to germinate and produce seeds (Weller 1990). Many species of edge plants, including those just listed, as well SCAT, SALA, *Typha* sp., LEOR, POHY, EUGR (Pierce 1994) and others were present in the SP zones of many sites and provide food to wildlife utilizing these wetlands.

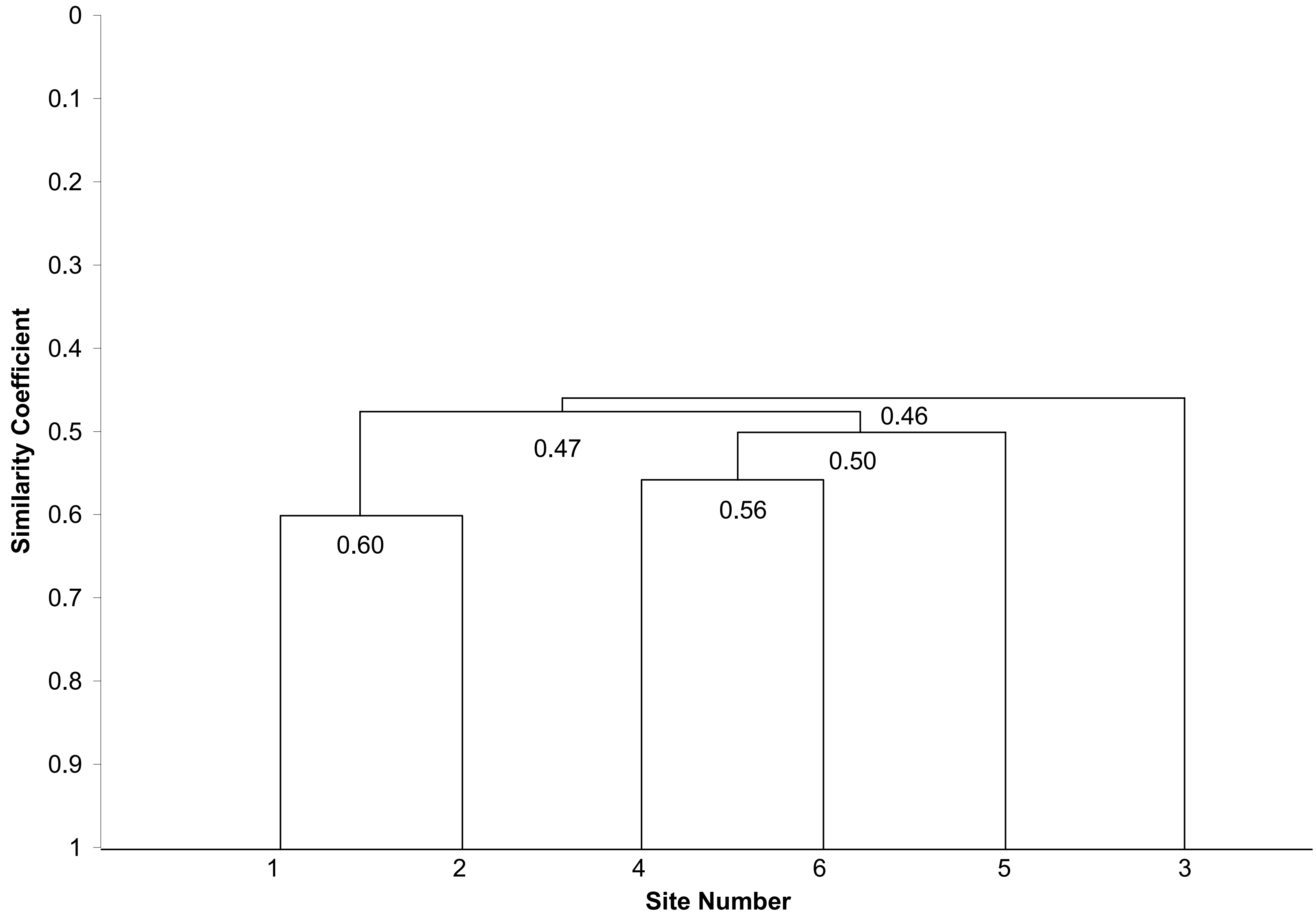
Similarity between sites

Site comparison using the Coefficient of Similarity was used to compare the six sites with one another to assess those that were the most similar and most dissimiliar when comparing vegetation data only (Table 17 and Figure 16). Honda and Medallion, with a similarity coefficient of 0.60 were the most similar. This may be attributed to the fact that these sites had the highest species richness and therefore had a greater probability of sharing a greater number of the same species. In addition they both contained the dominant species of POPR and ELOB. The next most similar sites were ODOT and Ross, with a coefficient of 0.56. Closely following this association was the relationship of ODOT WCA to these two sites, with a coefficient of 0.50. Again, this may be attributed to the species richness of each of these sites, which were similar and ranged in number from 43-47. The New Albany site was the least similar among all study sites. This is most likely due to the fact that New Albany site represented the lowest species richness of the group and was the only site to contain ERCA and WOPU, the latter of which was the most dominant species found in the SP of the Ross site. Typically, a coefficient of similarity of at least 0.50 indicates those communities being compared are of the same association (Barbour et al. 1999). Therefore, most of these sites are of the same association. Because three associations fall just short of the typically recognized coefficient of 0.50, these

Table 17. Floristic comparison of six wetland study sites using the Coefficient of Similarity, as determined by Sorenson's calculations

Site	1	2	3	4	5	6
1						
2	0.6					
3	0.43	0.48				
4	0.47	0.51	0.55			
5	0.44	0.49	0.41	0.52		
6	0.47	0.42	0.43	0.56	0.48	

Figure 16. Dendrogram showing degree of floristic similarity between six wetland mitigation sites.


Similarity Coefficient
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.46
0.47
0.50
0.56
0.60
1
2
4
6
5
3
Site Number

relationships may still likely be considered of the same association.

Diversity of sites

Diversity indices, including the Simpson index (C), Shannon-Wiener index (H') and evenness index (J) were calculated for comparison among the six sites (Table 18). Two important components of diversity are richness, the number of species in a given community, and evenness, the degree to which percent cover is distributed evenly among all the species in a community. Dominance and evenness are inverse properties (i.e. a community with low evenness will have a higher degree of dominance by one or more species that are present in larger quantities than other species in the community). Simpson's index is used to express dominance while the Shannon-Wiener index is used to express diversity.

Calculated C values for each of the wetlands determined ODOT has the lowest C value (0.056) and is therefore the site that experiences the least dominance by one or a few number of species. New Albany, with the highest C value (0.172), shows the greatest presence of dominant species among the six study sites. This relationship is also evident when revisiting Tables 7 and 8. In Table 7, it is obvious New Albany is dominated by the presence of WOPU, while the remaining 14 dominant species have much lower IV's. In contrast, when reviewing Table 8, the 15 dominant species at the ODOT site are much more similar in IV. The presence of a dominant species such as WOPU at the New Albany site may present a concern, even though this species is not identified as invasive. In a study reported in 2004, Houlahan and Findlay found that while invasive species are likely to dominate a vegetative community, other species identified as native and not invasive are just as likely to dominate and inhibit the growth of other species, thus resulting in decreased species diversity. Therefore, their study advocates the importance of ensuring no species are excessively dominant over others in the community.

When comparing H' values, ODOT, not surprisingly has the highest diversity (3.17) and New Albany is characterized by the lowest diversity (2.34). Because it is expected sites with higher diversity will yield more beneficial habitat and food sources for wildlife, it may be predicted that value to wildlife from each of the sites is present in the following order (in decreasing order of importance): ODOT, Ross, Medallion, ODOT WCA, Honda and New Albany.

High diversity on newly established sites is expected because many species may become initially established and it is expected diversity may decrease slightly when succession begins to

Table 18. Diversity indices calculated for each of the six wetlands in this study.

Index	1	2	3	4	5	6
Simpson (C)	0.103	0.106	0.172	0.056	0.076	0.060
D = 1 - C	0.897	0.894	0.828	0.944	0.924	0.940
Shannon-Wiener (H')	2.950	2.970	2.340	3.170	2.950	3.120
Evenness (J)	0.750	0.720	0.648	0.823	0.775	0.830

take place and competition for resources begins (Confer and Niering 1992). Studies have reported restored and/or created wetlands are characterized by higher species diversity than reference wetlands for at least the first three years of development. While species diversity of reference wetlands in Ohio was not available in the literature, 17 natural wetlands in Pennsylvania were determined to have an average H' of 2.1 (± 0.3) (Stauffer and Brooks 1997). Therefore, the diversity of all wetlands in this study exceeded that of these studied reference areas. Similarly, Ashworth (1997) reported reference wetlands received an H' of 1.13, while mitigated wetlands received scores between 1.31 and 1.49. A study conducted by Heaven et al. (2003) concluded constructed wetlands resulted in the presence of greater species richness than reference wetlands because of appropriate construction methods, including the transfer of salvaged wetland soil from those natural wetlands that were impacted as a result of project implementation.

Further validating the conclusions provided above are the results of calculating J for each site. A higher evenness score represents a site that is characterized by a lower number of species that are dominating present cover of vegetation in the wetland. A more even distribution of species results in a higher evenness score. In this calculation, the Ross site (J = 0.830) is slightly higher than the ODOT (0.823). Therefore, both sites have fairly even distribution of species and neither is greatly affected by the presence of a dominant species. New Albany received the lowest J score (0.648) and therefore the evenness of this site is most affected by dominant species representing a large percentage of vegetation cover at the site.

Reasons for observed diversity differences

Species richness and diversity at each site is likely attributable to many factors, including methods of site construction (i.e availability of a seed bank and/or plantings), species interactions (competition) at each site, and water availability in terms of inundation and/or saturation. While it is recognized the presence of a seed bank in the mitigated site may be one of the most important factors to determine success, this may not be result if the seed bank is not viable and seed addition/plantings may be necessary for success (Xiong et al. 2003). Typically, the interaction of many factors will lead to the resulting species richness of a site. After considering the effects of construction methods, effects such as seed germination, succession, flooding, and water quality will regulate structure of the plant community (Weller 1990).

Even though it is difficult to determine why particular sites have higher species diversity and cover than others, hypotheses concerning these results may be predicted. For example, as discussed in the introduction, studies have previously determined the use of seed banks and/or stockpiled soils to develop vegetation in mitigated wetlands are typically more successful than plantings. Vegetation at the two sites with the highest diversity in this study, Ross and ODOT, was established through the use of salvage hydric soil from wetlands that were impacted and seeding, and existing seed bank sources and seeding, respectively. Vegetation at those sites with relatively similar diversity, including Honda, Medallion, and ODOT WCA, was established through the use of one or more of the following measures: stockpiled hydric soils, seeding and/or seedbank. Therefore, these appear to be useful establishment methods when used either alone or in combination with another method. The site with the lowest diversity, New Albany, was established through use of a seed bank and plantings. Stauffer and Brooks (1997) concluded those wetlands constructed with salvaged marsh surface material from a natural wetland would be more successfully vegetated than those wetlands not constructed with salvaged material. However, it must be recognized the lower diversity at this site could be attributed to many reasons, including a seed bank that was less viable than those at other sites and/or unsuccessful establishment of plantings. This site was also characterized by one of the highest levels of the invasive species PHAR, so its lower species diversity could be partly attributed to poor management and control of this species.

Floristic Quality Assessement Index (FQAI) Scores

While the indices calculated above provide insight into the richness and evenness of communities in this study, the FQAI was calculated for each site to provide comparisons and draw conclusions concerning those sites which are representative of less disturbed environments. To calculate FQAI, the sum of the coefficients of conservatism (C of C) for each site was determined. C of C values have been assigned to all native taxa in Ohio (Appendix 2). Therefore, the C of C values for only those native species contribute to the overall FQAI score for each site. Percent cover of native species ranged from 70 to 98 percent, and Medallion and New Albany represent the lower and upper ranges, respectively (Table 19). Number of native species (N) range from 29 to 47, with ODOT WCA and Medallion representing the lower and upper ranges, respectively.

Calculated FQAI scores range from 10.7 to 18 (Table 19). Andreas et al. (2004) reported FQAI scores for natural wetlands that ranged from 19 to 23 for high quality mixed emergent marshes, 14.4 for a good quality mixed emergent marsh and 6.6 for a very disturbed mixed emergent marsh. New Albany and ODOT WCA received the lowest scores, both because they have the lowest species richness of native species and also because the average C of C values assigned to species at these sites were lower than the other sites (2 and 2.1 compared to 2.2 – 2.9 at the other four sites). Most species in this study were recognized as those with a C of C of 4 or less (Figure 17). These average C of C values indicate all wetlands in this study are dominated by widespread species that are able to adapt to many ranges. Those species defined by Andreas et al. (2004) as sensitive, in that they have a narrow range of ecological tolerances, have been assigned values between 6 and 10. Those sensitive species identified in this study include ASLE, BENI, ELTE, IRVI, POHY, VIAC and WOPU. Of these, only WOPU's presence at the Ross site, as indicated by an IV of 35, is representative of a dominant presence of a sensitive species. All others are present in infrequent stands at select sites with low cover. Therefore, while the sites in this study appear to be comparable to natural good quality mixed emergent marshes based on FQAI score comparison, it would be desirable if species that are less disturbance-tolerant were present to a greater extent.

ENVIRONMENTAL (SOIL) DATA

Introduction

When assessing percent moisture, pre and post-incubation NO_3^- levels and NH_4^+ levels and net mineralization and nitrification, there were significant differences among data collected from the same zones at each site (e.g. data from transect 3 in Honda OF was significantly different from data collected from transect 4 in Honda OF). This difference was observed and inferred to be significant. Spatial heterogeneity in soil may be the cause of this observation (Dick 2003). Similarly Davidson and Hackler (1994) report rates of nitrification are affected by much more than the availability of NH_4^+ and include heterogeneous factors such as acidity, allelopathic inhibitors, soil water content, and other varying soil and microbial population characteristics. Because of the variability present among similar zones from different transects at the same site (Appendix 5), means of each parameter sampled were determined across each zone of each site and used for further analysis (Table 20).

Table 19. Parameters calculated in association with determination of Floristic Quality Assessment Index (FQAI) for each of six sites. Those genera not identified to species level, were not included in calculations.

Site Number	1	2	3	4	5	6
Sum of relative cover (A)*	0.89	0.7	0.98	0.84	0.8	0.7985
Sum of C of C †	87	124	63	86	58	95
FQAI N (species richness) ‡	40	47	30	35	29	33
FQAI Score	13.8	18	11.5	14.5	10.7	16.6
Average C of C	2.2	2.6	2.1	2.5	2	2.9
Relative cover sensitive spp **	0.005	0.05	0.35	0.02	0.004	0.1

* , Expressed as a decimal, rather than a percent as in IV calculations. Does not include cover of non-native species; † , Sum of C of C values (App 2) for native species only; ‡ , Number of native species present at each site; ** Relative cover, expressed as a decimal, of those species with a C of C between 6 and 10.

Figure 17. Distribution of species in Coefficient of Conservatism (C of C) categories.

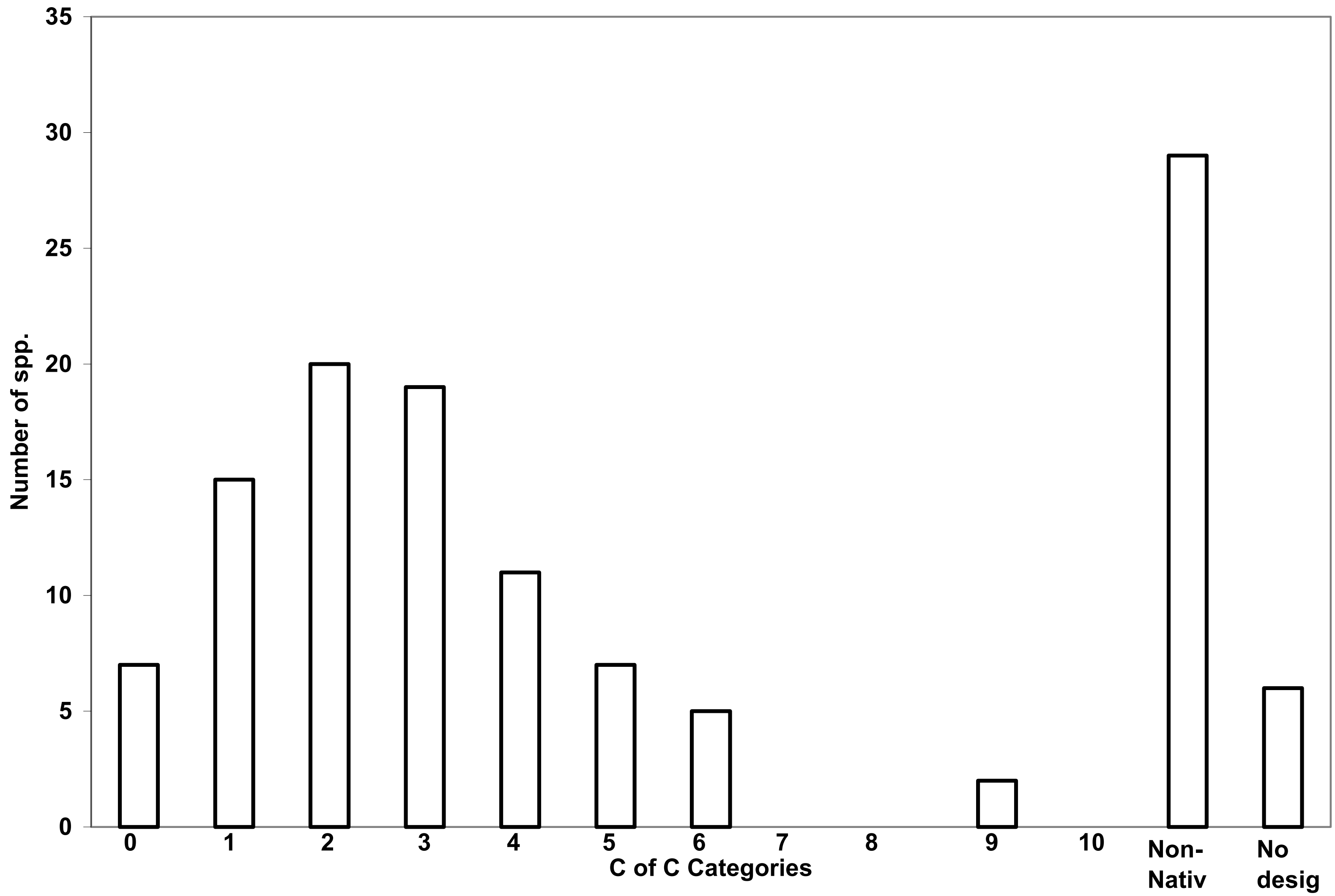

Number of spp.
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
8
9
10
Non-
Nativ
No
desig
C of C Categories

Table 20. Means of soil parameter data collected from each of three zones (old field, seasonally pooled and permanently pooled wetland) at six study sites.

Wetland *	moist(%)	NO_3^- pre µg/g	NH_4^+pre µg/g	NO_3^- post µg/g	NH_4^+ post µg/g	NMin† µg/g	Nit ‡ µg/g
1 OF	21.40	0.48	8.40	0.45	7.09	-1.34	-0.03
1 SP	27.74	0.18	3.99	0.30	6.67	2.81	0.13
1 PW	32.76	0.52	5.93	0.67	7.96	2.17	0.14
2 OF	21.61	1.13	0.90	0.38	0.89	-0.76	-0.75
2 SP	21.90	1.64	1.86	0.44	1.31	-1.74	-1.19
2 PW	27.79	0.00	1.23	0.03	1.30	0.09	0.03
3 OF	17.00	0.55	4.59	0.00	1.45	-3.69	-0.55
3 SP	24.00	2.42	8.84	1.87	5.84	-3.54	-0.54
3 PW	31.90	0.00	0.00	0.51	1.27	1.77	0.51
4 OF	25.77	0.73	5.41	3.91	6.17	2.15	3.19
4 SP	24.44	0.81	9.02	0.91	5.20	-4.01	-0.20
4 PW	30.30	2.02	13.40	3.74	4.12	7.56	1.73
5 OF	18.20	0.67	3.85	5.76	3.63	4.88	5.09
5 SP	23.02	0.86	1.96	2.32	4.01	3.51	1.46
5 PW	26.20	0.00	3.87	0.61	4.72	1.46	0.02
6 OF	22.00	0.92	2.20	0.53	1.47	-1.12	-0.39
6 SP	23.83	1.47	1.71	0.30	1.54	-1.34	-1.17
6 PW	27.53	0.00	1.51	0.11	2.27	0.85	0.08

*, Wetland sites: 1(Honda); 2(Medallion); 3(New Albany); 4(ODOT); 5(ODOT WCA); and 6(Ross); † Nitrogen mineralization; ‡ Nitrification

Moisture

Data from each of the three zones at each of the six sites follows an expected trend of increasing moisture across the gradient from OF to PW (Table 20). Percent moisture in the OF at each site varied from a low of 17 to a high of 25.77. Percent moisture in the SP of each site ranged from a low of 21.9 to a high of 27.74. Percent moisture in the PW of each site ranged from a low of 26.2 to a high of 32.76 (Figure 18).

Nitrate and Ammonium pools: Introduction

When assessing nitrate pools in each of the three zones at each of the three sites, trends vary among the six sites. Numerous studies show nitrate pools decrease significantly in zones of permanent inundation because anaerobic conditions are dominant and oxygen is necessary for the process of nitrification to occur (Gilliam et al. 1999). Therefore, it is expected nitrate pools would decrease across the gradient from OF to PW and would be low or absent in permanently inundated areas. This general trend was not observed at any of the six sites. Therefore, the zones at each site will be addressed separately to explain those individual results found at each site.

In reference to ammonium pools, it is expected these levels would increase across the gradient from OF to PW. In the OF, NH_4^+ levels are expected to be low because ammonium is necessary for plant growth and will be assimilated into plants, particularly early in the growing season, which is when these samples were collected, when nutrient need is high. Plant uptake of NH_4^+ is negligible in permanent pools of inundation because few species are present in zones of permanent standing water. Of those species that may be present, their cover is likely to be much lower than vegetation cover present in OF and SP zones.

Old field

Extractable nitrate pools at each of the six sites in the OF were low (Figure 19). Soil data was collected near the beginning of the growing season, at the time when plant growth is just beginning and is very rapid. During this period, it is expected nitrate levels would be low because uptake by plants is high (Fisher, 1996).

Extractable ammonium pools at each of the six sites in the OF were significantly different among most sites and varied from a low of 0.90 µg NH_4^+-N/g soil at the Medallion site to a high of 8.4 µg NH_4^+-N/g soil at the Honda site. The range of values found in this study are higher than those reported by Fisher (1996), who found in the early growing season ammonium levels

Figure 18. Average percent moisture across all sites across the gradient from old field to permanently pooled wetland.

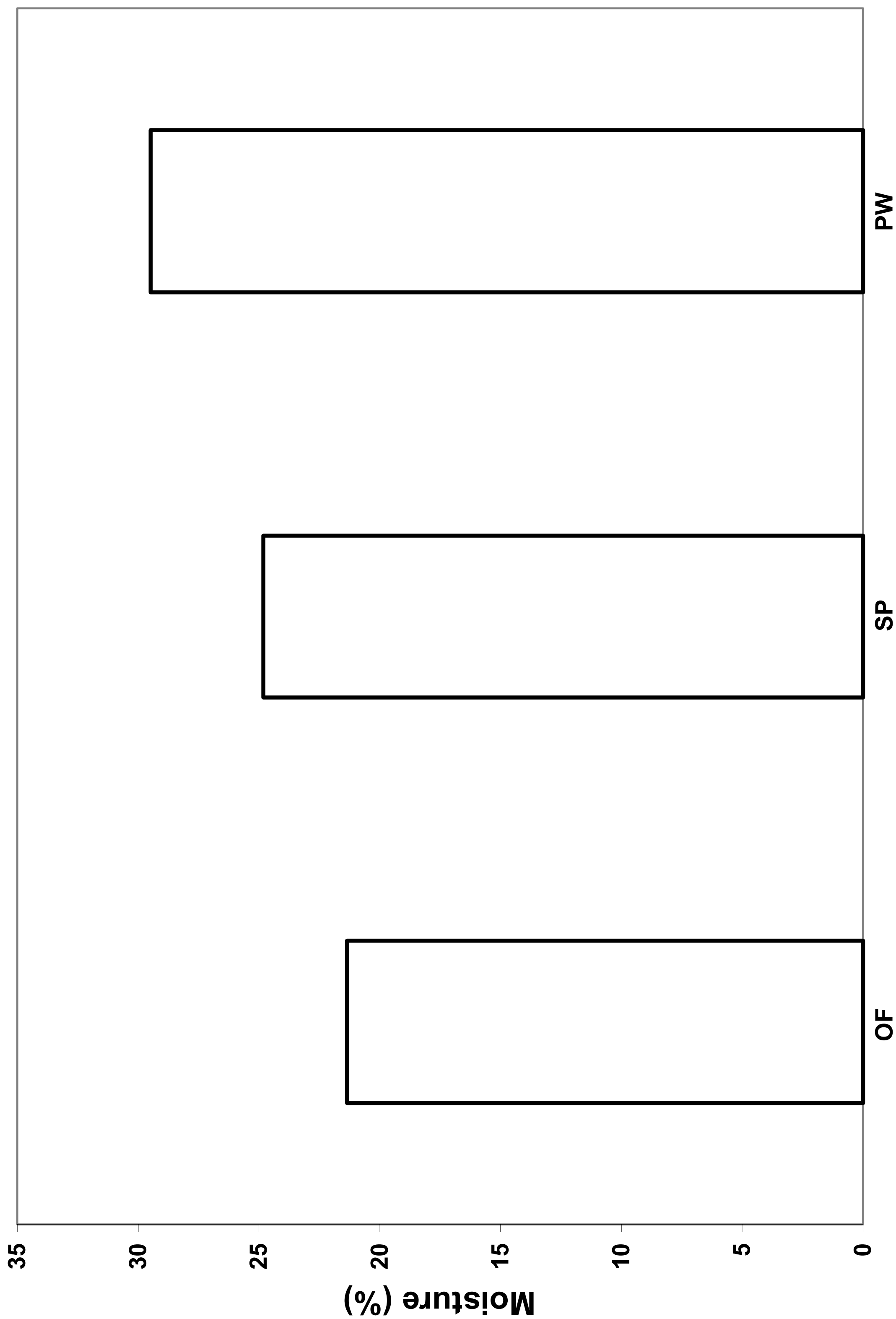
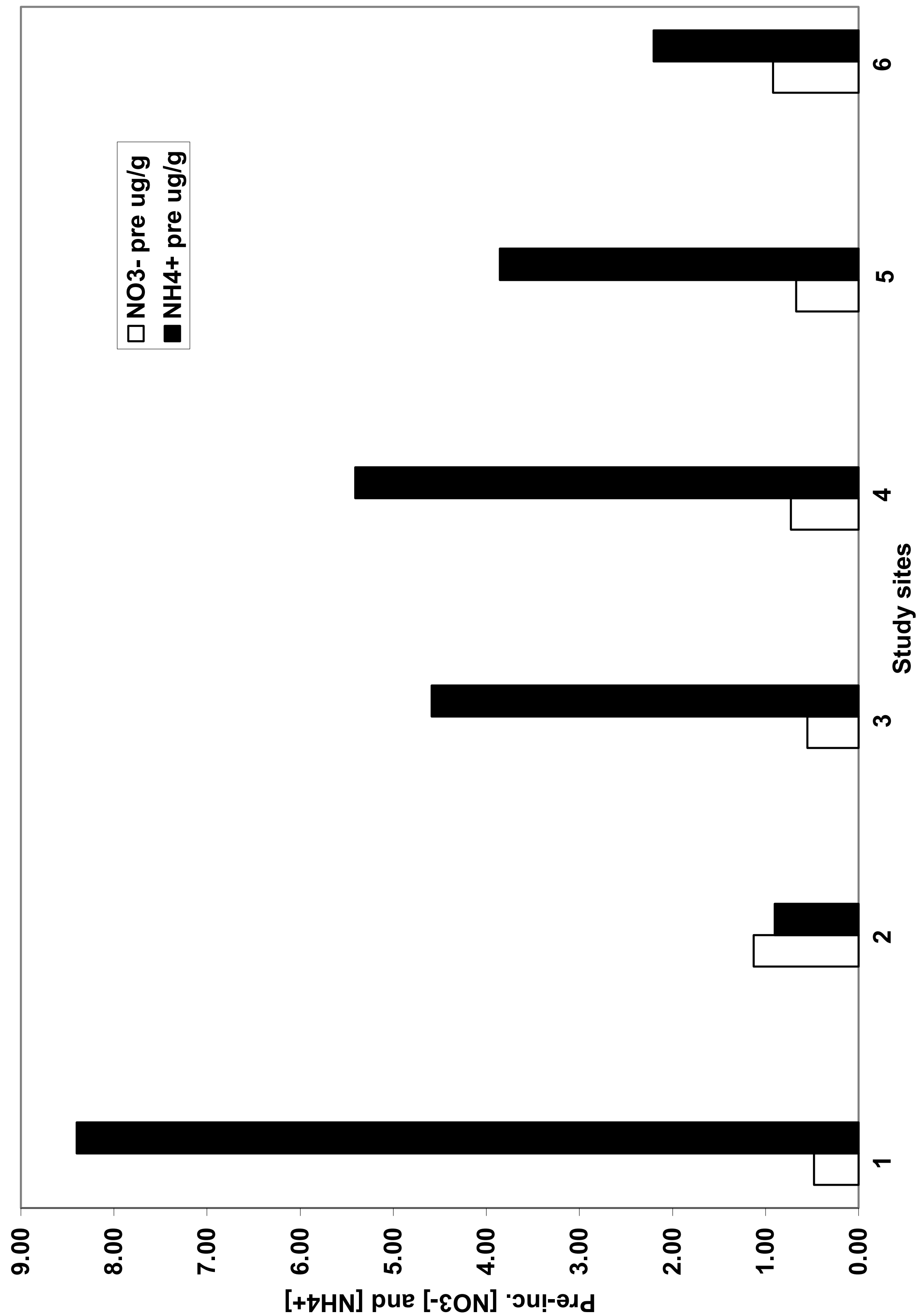

Moisture (%)
0
5
10
15
20
25
30
35
OF
SP
PW

Figure 19. Summary of NO_3^- (µg NO_3^- - N/g soil) and NH_4^+ (µg NH_4^+ - N/g soil) pools in the OF zones of each study site.



Pre-inc. [NO3-] and [NH4+]
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1
2
3
4
5
6
Study sites
NO3- pre ug/g
NH4+ pre ug/g

were very small. Small levels of NH_4^+ are attributed primarily to two factors; one, plant uptake during the growing season and 2) rapid nitrification of NH_4^+ to NO_3^- by microbes. Therefore, it appears the Honda site either had the least amount of uptake by plants and/or experienced the lowest percentage of nitrifying microorganisms. Because of the relatively high species richness within the OF at Honda (28 species) and the high percent cover of species in this zone (191.75), it is expected plant uptake would be relatively high and ammonium levels should be low. The data collected in this study reflecting a high ammonium level at this site is most likely attributed to the fact that a very limited number of soil samples were taken. Based on knowledge gained from soil studies in regards to heterogeneity present in soil, it is expected had additional samples been taken at Honda OF, lower levels of ammonium would have been found in this zone. It is expected sites, including Medallion and Ross, with low levels of NH_4^+ are experiencing either rapid uptake by plants in the early growing season and/or experiencing higher levels of microbial transformation of NH_4^+ to NO_3^-. Nitrification is occurring to some extent, as Medallion and Ross reported the highest levels of pre-incubation NO_3^- levels.

Seasonally inundated

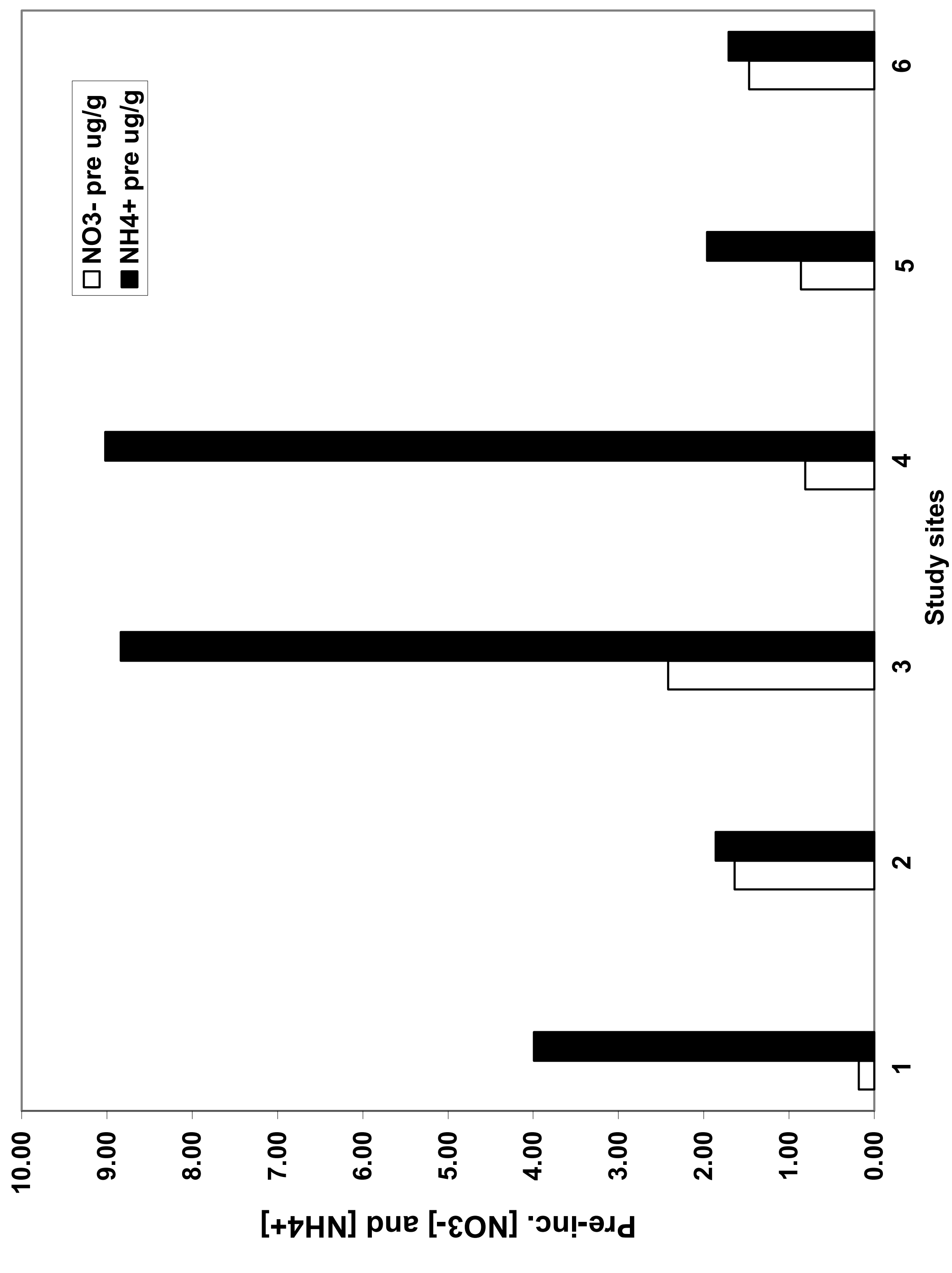
Extractable nitrate pools at each of the six sites in the SP zones were low (Figure 20). These results correspond to the fact it appears a large amount of nitrate had been taken up by rapidly growing plants at the beginning of the growing season. Gilliam et al. (1999) reported nitrate levels of 1.8 $\pm$ 0.5 µg NO_3^- - N/g soil in created wetland zones; therefore values collected in this study correspond.

Extractable ammonium pools at each of the six sites in the SP zones varied from a low of 1.7 soil to a high of 9.02 µg NH_4^+- N/g soil. In Fisher's study (1996), he found when a transition zone is inundated, ammonium pools will be higher than nitrate pools from the same sample. During this study, soil samples were taken from all sites at a time when the seasonally inundated zones all contained standing water. All sites exhibited higher levels of NH_4^+ than nitrate and therefore correspond to the findings of Fisher. At the time of soil collections for this study, anaerobic conditions had been present for a sufficient amount of time to inhibit the microbial mediated transformation of ammonium to nitrate, a process which requires oxygen.

Permanently inundated

Extractable nitrate pools at each of the six sites in the PW zones were zero for four of the six sites (Figure 21). This is attributed to the fact that in permanently inundated conditions, the

Figure 20. Summary of NO_3^- (µg NO_3^- - N/g soil) and NH_4^+ (µg NH_4^+ - N/g soil) pools in the SP zones of each study site.


NO3- pre ug/g
NH4+ pre ug/g
Pre-inc. [NO3-] and [NH4+]
Study sites
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1
2
3
4
5
6

process of nitrification is severely limited. This observation is supported by numerous previous studies and occurred as a result of the lack of oxygen present to perform the process of nitrification. In those two sites, Honda and ODOT, with detectable levels of nitrate present in the PW, this may be due to the presence of a population of nitrifying bacteria within an aerobic layer of inundated soil. It has been documented that oxygen may be present in layers even in soils that are inundated for long periods of time (Mitsch and Gosselink 1993). Certain zones of nitrification may be present and it appears that these zones were sampled for each of these two particular sites.

Extractable ammonium pools at each of the six sites in the PW zones ranged from zero to 13.4 μg NH_4^+ - N/g soil (Figure 21). Levels of ammonium in permanently inundated pools are expected to be high, both because plant uptake is typically negligible in this zone and also because the bacterial mediated process of nitrification is inhibited in anaerobic conditions. Therefore the highest NH_4^+ level found in this study, at the ODOT site, is readily explained by these two factors. Excluding the value of 0 found at the New Albany site, the other values, while relatively low, are all higher than those corresponding NH_4^+ levels found from the same sites in the SP zones. Therefore, this trend does appear to correspond to that which would be expected as one moves from a seasonally inundated zone to a permanently inundated zone with lower levels of plant uptake and nitrifying bacteria.

Fluxes: Net Nitrification (Nit) and Net Nitrogen mineralization (Nmin)

Old field

Net nitrification and mineralization results were varied among the six sites. Other studies have shown high variability within and between sites (Duncan and Groffman 1994), so while results may not follow expected general trends, they are not surprising. Nmin and Nit values were negative in the OF in four of the six sites in this study (Figure 22). These findings are representative of the process of immobilization in each of these four sites. At the Honda and New Albany site, almost all immobilization took place in the form of microbial-mediated uptake of NH_4^+. At Medallion and Ross, larger amounts of NO_3^- were immobilized. In immobilization, NH_4^+ and NO_3^- are not available for plant uptake. Microbial populations are capable of immobilizing nutrients and the varying microbial processes found at different sites are likely due to a variety of factors including organic matter quality and quantity, hydrology, plant type and dynamics present and any disturbances present (Groffman et al. 1996).

Figure 21. Summary of NO_3^- (µg NO_3^- - N/g soil) and NH_4^+ (µg NH_4^+ - N/g soil) pools in the PW zones of each study site.

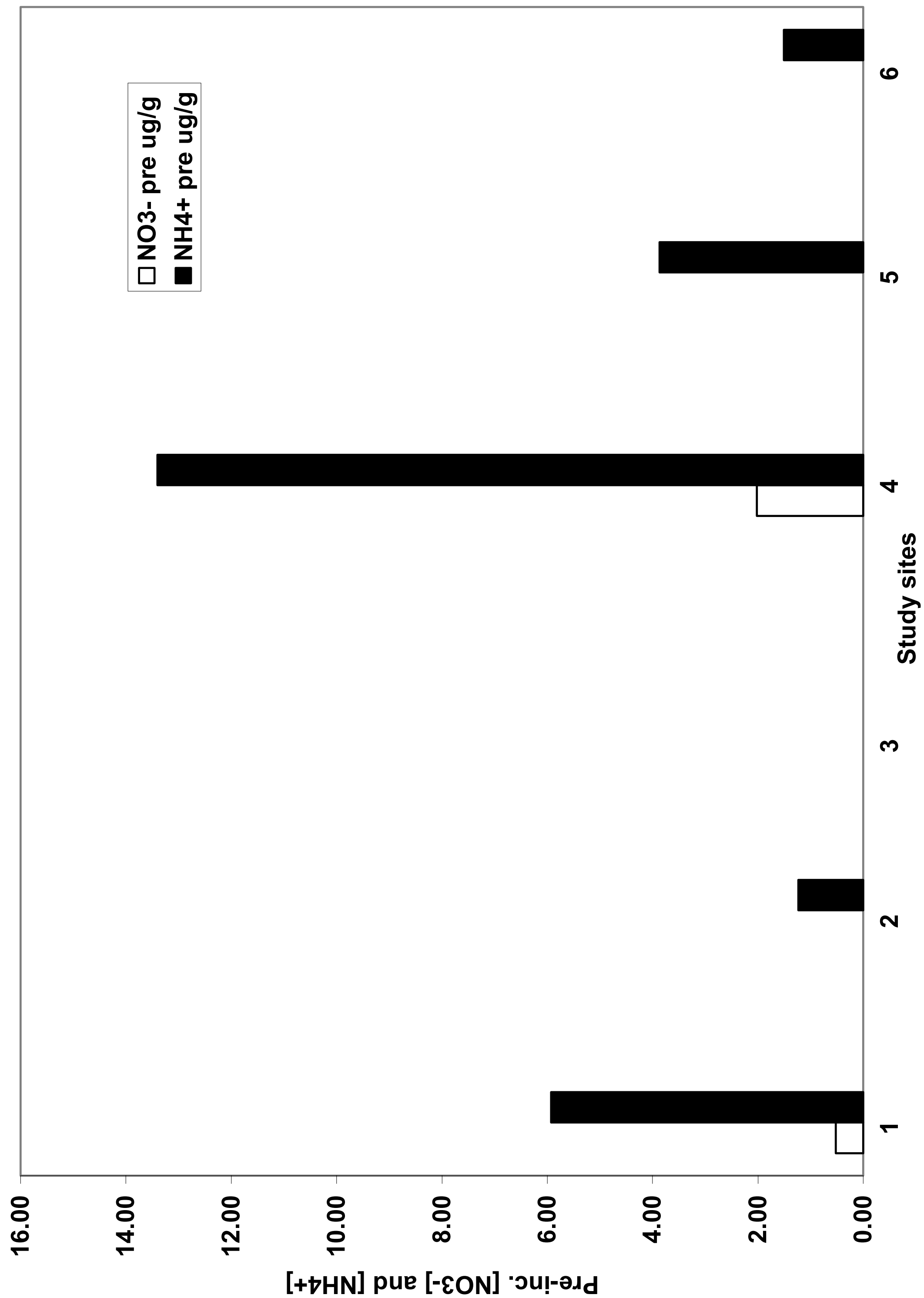
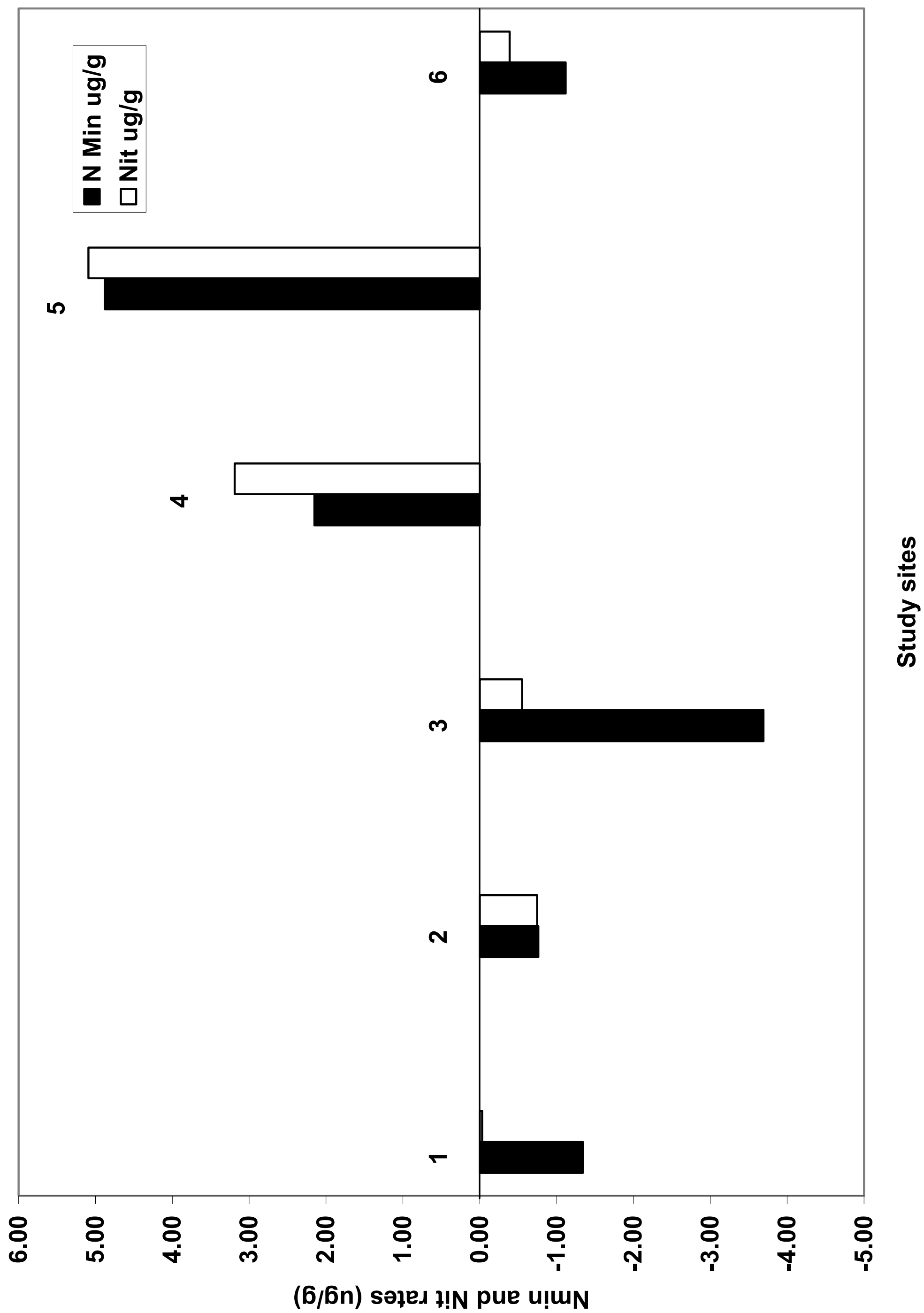

Pre-inc. [NO3-] and [NH4+]
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1
2
3
4
5
6
Study sites
NO3- pre ug/g
NH4+ pre ug/g

Figure 22. Net nitrification (μg NO_3^- - N/g soil) and N mineralization (μg N/g soil) in the OF zones of each study site.


N Min ug/g
Nit ug/g
Nmin and Nit rates (ug/g)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
1
2
3
4
5
6
Study sites

Duncan and Groffman reported on the similarities in Nmin and Nit exhibited by natural and created wetlands. They stated the presence of an active microbial population indicates wetlands have a significant potential for immobilization of nutrients and degradation of organic contaminants (1994). Because immobilization was observed in this study, it may be inferred that beneficial microbial populations are present in this zone. However, in contrast, because immobilization was the dominant process in this zone at four of the six sites, available forms of nitrogen are not present for plant uptake.

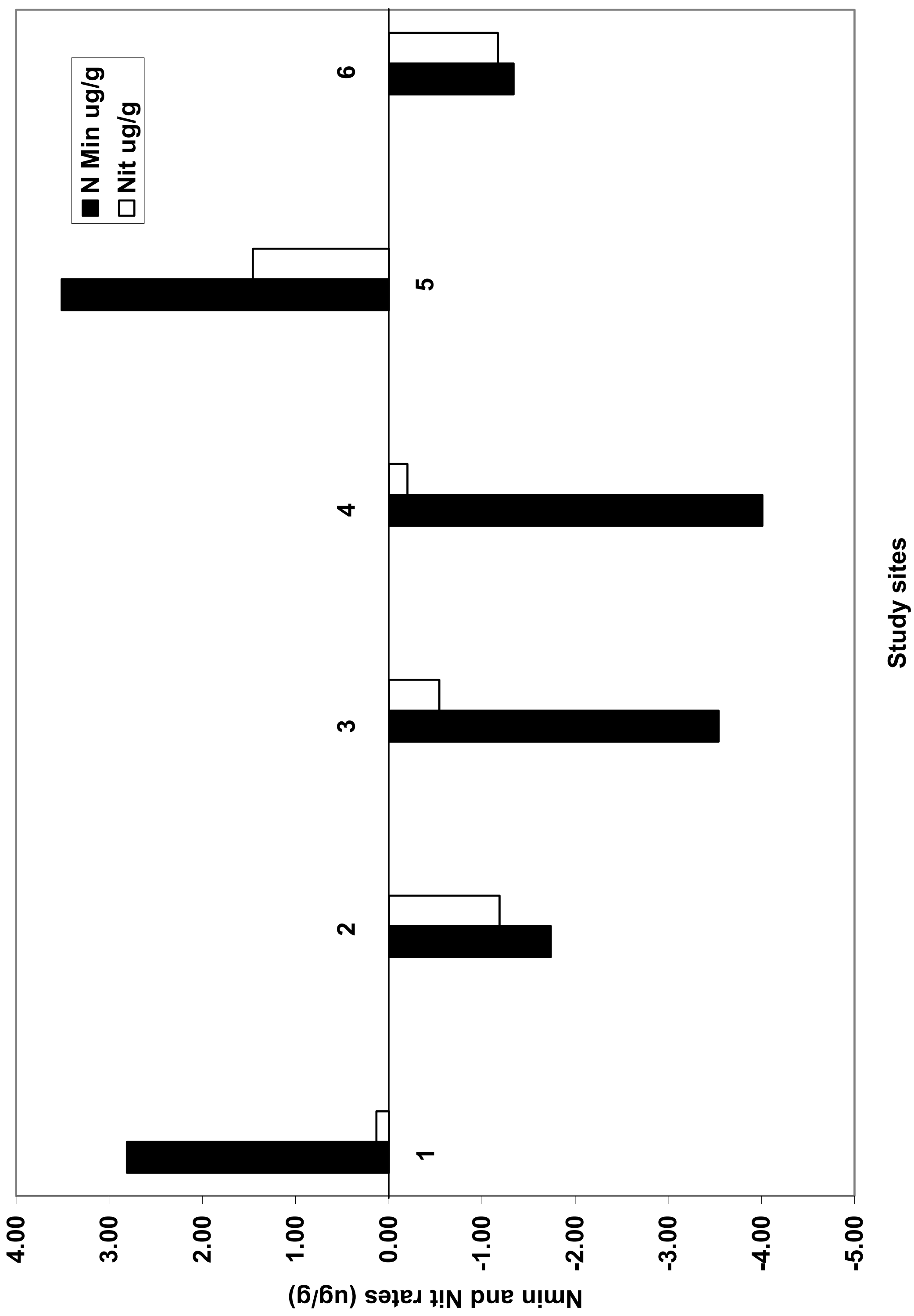
The presence of immobilizing bacteria in the OF at each site is not necessarily that which would be expected. Typically, organic matter accumulates more rapidly in wetter soils. Organic matter provides the substrate for most microbial processes (Groffman et al. 1996). Therefore, one would expect to find immobilization rates in the SP and/or PW zones of the wetland. As will be discussed shortly, higher rates of immobilization were found in the SP zones of several sites but were not observed in the PW zones.

In the ODOT and ODOT WCA OF zones, positive rates of nitrification and mineralization were present. At ODOT WCA, all N mineralized was nitrified. This suggests this site was affected most by the population of bacteria that is responsible for nitrification. These results are supportive of information presented in the literature indicating that in aerobic soil conditions, continual conversion of NH_4^+ to NO_3^- will take place.

Seasonally inundated

In all sites, excluding the Honda site, levels of nitrification decreased from the OF to the SP zones (Figure 23). This is again, as described above, because the aerobic process of nitrification is inhibited in anaerobic zones. In general nitrogen mineralization is dominated by either immobilization or ammonification. These findings are in direct contrast to Dick's findings (2003), who reported that almost all mineralization was due to nitrification. Nitrification and mineralization levels are negative in four of the six sites, indicating presence of the process of immobilization. As discussed above, microbial communities capable of immobilizing nutrients are likely to be present in wetter areas where organic matter is more likely to accumulate. In the remaining two sites, Honda and ODOT WCA, nitrogen mineralization was affected by low or almost zero levels of nitrification. This is an expected response in a seasonally inundated area, particularly when data collected for this study was done so at a time when this zone was

Figure 23. Net nitrification (µg NO_3^- N/g soil) and N mineralization (µg N/g soil) in the SP zones of each study site.


N Min ug/g
Nit ug/g
1
2
3
4
5
6
Study sites
4.00
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
Nmin and Nit rates (ug/g)

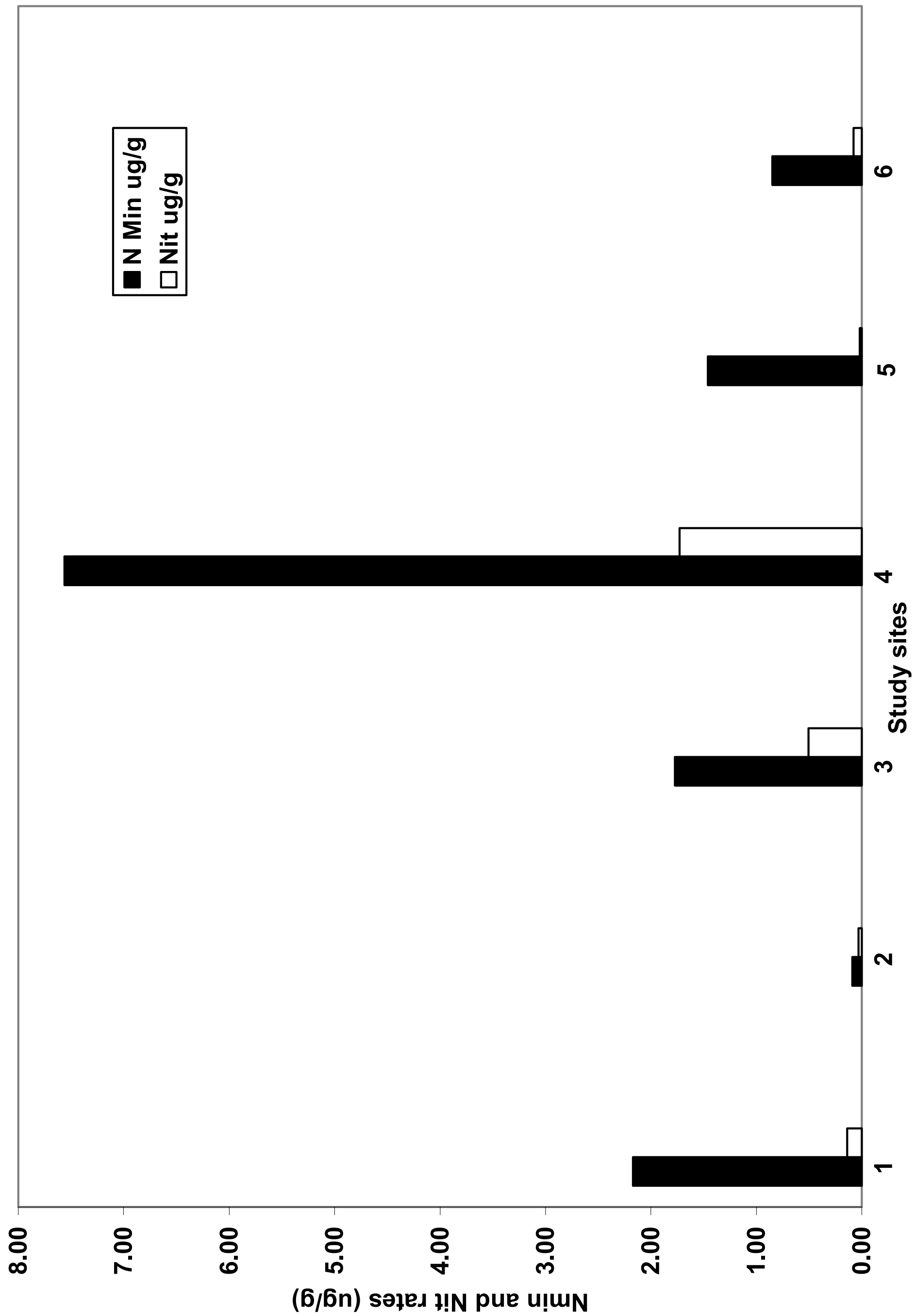
inundated. These results indicate little conversion of NH_4^+ to NO_3^- and thereby indicate the importance of the mineralization of organic nitrogen ending with ammonification. The Honda and ODOT WCA are the only sites in the study that were determined to have available forms of nitrogen in the SP zones. Primarily NH_4^+ and some NO_3^- are available in these zones for plant uptake.

Permanently inundated

Trends among the permanently inundated zones of all study sites were more similar than those that occurred in the other two zones of study (Figure 24). Almost all mineralization is represented by the end process of ammonification and nitrification is absent or rare. This is comparable to the findings of Gilliam and Fisher (1995), who reported no levels of nitrification in permanently inundated mitigation wetland soil. Small levels of nitrification are expected in the PW zone because the aerobic process of nitrification is inhibited in zones of permanent inundation. The highest level of nitrification occurred in the ODOT site, likely due to the presence of an aerobic layer that allowed the conversion of NH_4^+ to NO_3^-. In the PW zones of all sites, nitrogen mineralization was positive, again indicating the importance of the mineralization of organic nitrogen ending with ammonification.

This zone across all six sites did not experience any immobilization of inorganic nitrogen compounds. Therefore, it is expected bacterial populations responsible for the process of ammonification are present; while those responsible for immobilization are absent. In all sites except Honda and ODOT WCA, levels of mineralization were higher in the PW zones of each site than in any other zones. Zak and Grigal suggest that rate of Nmin should reach a maximum when microbial biomass is at a minimum and when immobilization rates are low (1991). This in fact appears to be what has happened, as nearly all mineralization occurred as a result of ammonification. Therefore, microbes responsible for the conversion of NH_4^+ to NO_3^- are absent or in low numbers. In addition, microbes responsible for immobilization of NH_4^+ appear to be absent. As discussed before, populations of immobilizing bacteria indicate the health of a wetland system and therefore, it is expected that as these wetlands mature, they should experience the presence of these microbes. Without a presence of microbes in this zone, potential for immobilization of nutrients and degradation of organic contaminants in inhibited (Duncan and Groffman 1994). Their potential absence currently in this zone of permanent inundation represents the potential that organic matter has not accumulated in this zone to a

Figure 24. Net nitrification ($\mu g\ NO_3^- - N/g$ soil) and N mineralization (μg N/g soil) in the PW zones of each study site.


N Min ug/g
Nit ug/g
Nmin and Nit rates (ug/g)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
Study sites
1
2
3
4
5
6

sufficient extent to support a diverse and active microbial population. Therefore, these zones of the wetlands may not be adequately providing water quality functions of removing pollutants.

In summary, it appears as though as sites experienced mineralization and rarely was nitrification a significant part of this process. Nitrification is not expected to be a dominant reaction in the SP or PW zones of these zones, as oxygen levels are severely inhibited in anaerobic zones. In those zones that did show nitrification, the presence of aerobic layer within the inundated zone is expected to be the cause of this result, which provided the presence of an available form of nitrogen, NO_3^-, for vegetation in these areas. It is important that mineralization was present in many of the zones of the sites, as this indicates the presence of NH_4^+, which is available for plant uptake and continued vegetative growth. The exceptions to this are the Medallion, New Albany and Ross sites, which experienced little mineralization and were characterized primarily be immobilization. This is a concern, as this indicates little nitrogen is available to plants at this site. However, as stated before, because soil is characterized by spatial heterogeneity, it is expected had additional soil samples been taken, results would have indicated that available forms of nitrogen are present in the soil. This must be assumed because the presence of high species richness at each of these sites as indicated by the vegetation parameter of this study must be supported by available forms of nitrogen necessary for continued growth and support of the vegetation.

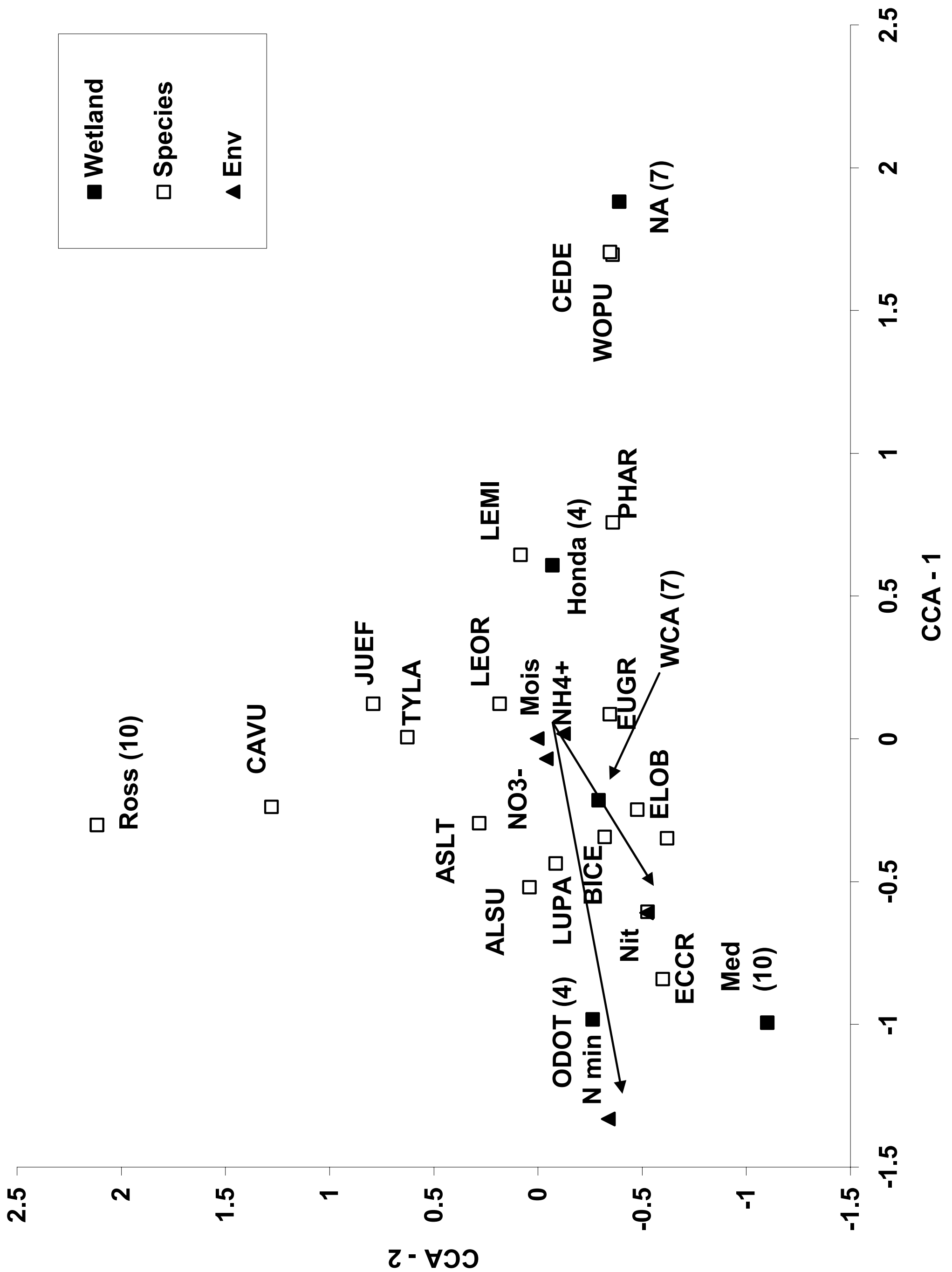
CHAPTER V
SYNTHESIS AND CONCLUSIONS

Canonical correspondence analysis (CCA) was used to assess the relationship between environmental and species data among and between sites. When comparing the mean importance values of all species across all sites and the mean environmental data across each of the six sites, CCA produced an ordination diagram showing large separation of each of the six sites (Figure 25). Sites most similar based on location in ordination space are ODOT WCA and ODOT. Based on this interpretation of collected data, there are fewer similarities among sites of similar age. For example, ODOT, a 4 year old site, is more closely related to WCA, a seven year old site, than it is to Honda, the other 4 year old site in this study. ODOT and New Albany, a 7 year old site, are the most dissimiliar of sites observed. The second most dissimiliar pair of sites based on this ordination is Ross and Medallion, the two oldest sites in this study.

Based on the comparison of location of species in ordination space to the IVs obtained for each species in this study (Appendix 2), species with a large IV for a particular site proved to be useful in providing separation of sites from one another. For example, the highest IV of CAVU (8.9) was found at the Ross site, while other sites contained IVs for this species ranging from 0.9-2.93. Because of the predominance of this species at the Ross site, CAVU is one of three species separated from the majority of the remaining vegetation in the group. The other two species providing high site separation are CEDE and WOPU, which allowed for separation of New Albany from the group based on the fact that CEDE was found only in two sites and at a much higher IV (8.45 vs 1.26) in New Albany than Honda. Also, WOPU was the most dominant species, with an IV of 26.1, at the New Albany site. In reference to the Honda site, LEMI with an IV of 24.41, played the most critical role in Honda's separation from the remainder of the sites. In reference to the Medallion site, the species with the highest IV at this site, ECCR, provided a sufficient amount of difference from the other sites studied to provide separation of this site. The ODOT WCA site, as discussed previously, is a site with one of greatest diversity (H') scores and one received one of the highest evenness scores (J). This is reflected in this CCA ordination diagram because this site is located closest to the center of the diagram and is in close proximity to the greatest number of different species.

When comparing site species and environmental data as a whole (in comparison to analysis based on each of the three zones at each site), those environmental variables that were

Figure 25. Canonical correspondence analysis created as a result of comparing the mean importance values of all species across each of the six sites and the mean environmental data across each of the six sites.



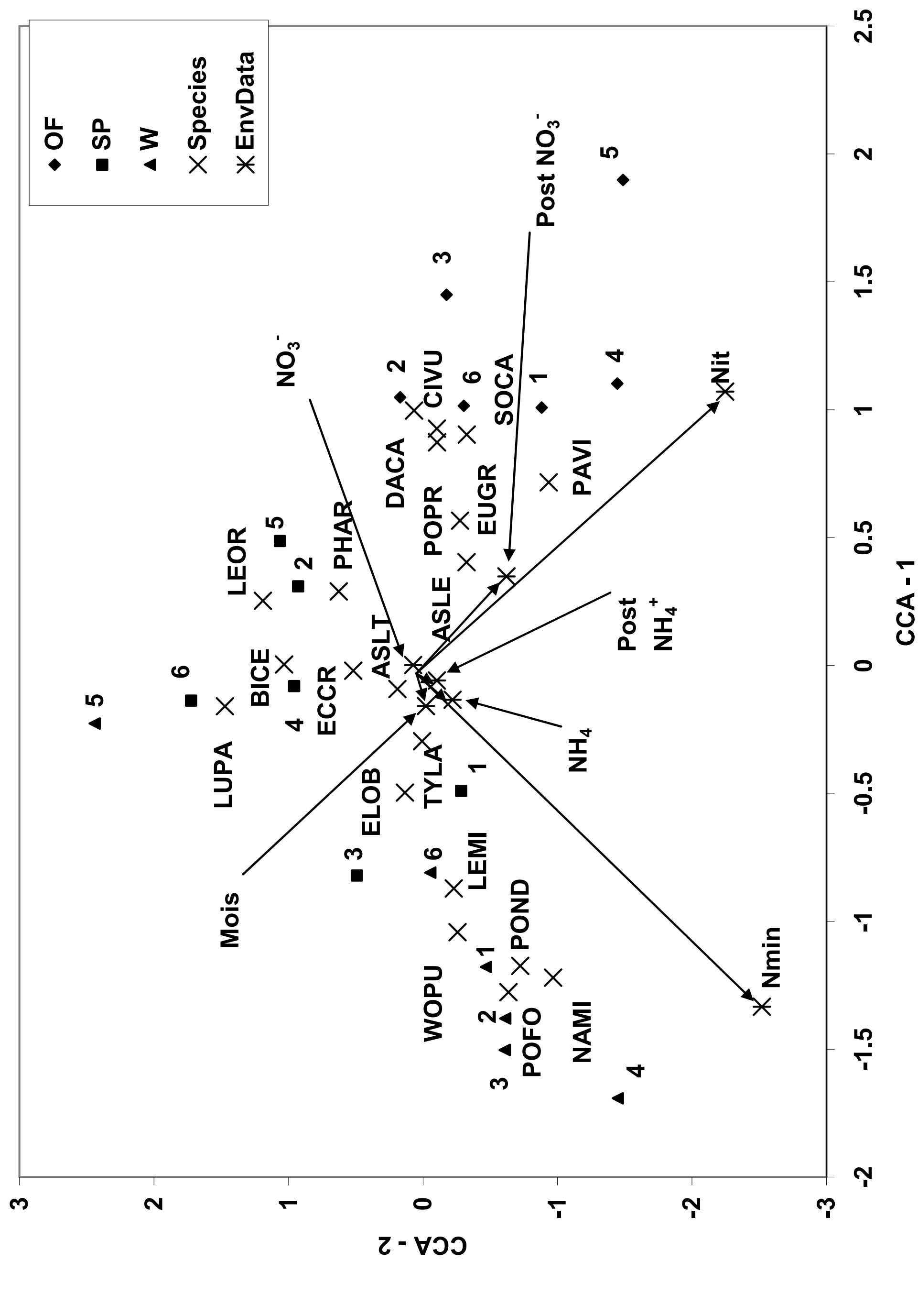
Wetland
Species
Env
CCA - 1
CCA - 2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5
Ross (10)
CAVU
JUEF
TYLA
LEOR
LEMI
Mois
NH4+
NO3-
ASLT
ALSU
LUPA
BICE
ODOT (4)
N min
Nit
ECCR
Med
(10)
ELOB
EUGR
WCA (7)
Honda (4)
PHAR
WOPU
CEDE
NA (7)

most prominent in separating the sites from one another were nitrogen mineralization and nitrification. Nitrate pools, ammonium pools and percent moisture at each of the sites was not found to provide meaningful information for site separation. Nmin was determined to be the most important environmental variable separating the ODOT site. This is due to the fact this site exhibited the highest rates of nitrification in the PW zone and the second highest rates of nitrification in the OF zones. While N pools were not of sufficient difference to provide site separation, it is interesting to note N fluxes were useful in differentiating the sites.

When comparing species and environmental data from each of the three zones at each of the six sites, a reasonably good separation of OF, SP and PW zones occurred (Figure 26). The most significantly different zone and site was the ODOT WCA OF. This is likely because this zone at ODOT WCA was the OF zone in this study to experience the highest rates of NMin and Nit. Those species determined to be most important in separating the zones into OF, SP and W were POPR, DACA, CIVU, SOCA, EUGR, ASLE, PAVI; LUPA, LEOR, BICE, ECCR, PHAR, ASLT, TYLA, ELOB; and POND, NAMI, POFO, WOPU and LEMA, respectively.

When comparing species (Appendix 4) and environmental data (Table 20) from each of the three zones at each of the six sites, those environmental variables that were most prominent in separating the sites from one another were nitrogen mineralization, nitrification, and post-inundation levels of NO_3^-. These environmental parameters allowed separation of the OF and PW zones, of which the first two environmental parameters played the most significant role. On average, Nmin rates were higher in PW zones than other zones, therefore the length of this environmental vector aligned in the direction of the PW zones is representative of this importance. Nit rates were highest in the ODOT and ODOT WCA OF zones, therefore this correlation is explained by the location of these data points for these two sites in closer proximity to the environmental vector line for Nit than any of the other OF zone points. Because no environmental parameter vectors are oriented in the direction of SP data points, with the exception of the Honda SP data point, it may be inferred that presence of dominant vegetation in the SP zones, including LUPA, LEOR and BICE, were more important differentiating factors for this zone. Environmental variables were likely not efficient in providing separation of SP zones because the data collected for this zone was variable and did not follow any identifiable trends. One recognized limitation of CCA is that it assumes all environmental variables are constant

Figure 26. Canonical correspondence analysis created as a result of comparing the importance values of all species present in each of the zones of OF, SP and PW and the mean environmental data from each of the OF, SP and PW zones.



OF
SP
W
Species
EnvData
CCA - 1
CCA - 2
Post NO_3^-
NO_3^-
Nit
Nmin
Mois
NH_4
Post NH_4^+
LEOR
PHAR
BICE
ECCR
ASLT
ASLE
LUPA
ELOB
TYLA
LEMI
POND
WOPU
POFO
NAMI
DACA
CIVU
SOCA
POPR
EUGR
PAVI

within a site. Variation within a site has been determined to be a difficulty with direct gradient analysis techniques in general (Palmer 1993). Therefore, as discussed previously, soils are heterogeneous over spatial and temporal scales. Even though it is recognized that CCA directly compares environmental and species data, a more adequate and recognizable site and zone separation appears to have occurred based on interpretation of species data rather than environmental data.

In conclusion, a comparison of environmental data and species data collected from six wetland study sites in Central Ohio has shown wetlands of similar age exhibit significant differences in how they are progressing towards natural systems. Results of vegetative data collection show, for the most part, all studied wetlands contain relatively high species richness and percent cover of hydrophytes. Results of species diversity, presence of invasive species, presence of native and non-native species, and FQAI scores were quite varied among the sites, the results of which are likely due to a combination of many factors. These varying results could be attributed to many factors including initial planning and construction (i.e. site selection, introduction of hydrology, and vegetation establishment methods) various different management and monitoring techniques (i.e. different or unclear goals in mind during monitoring, lack of monitoring and controlling invasive spp., etc.) and other uncontrollable biotic (i.e. herbivory) and abiotic (i.e. drought, excessive rain) variables.

Vegetation data collected does conclude that all sites are characterized, even though to different degrees, by diverse species. Therefore, it is expected each of these wetlands should function to provide benefits of wildlife habitat and sediment retention. Those sites represented by lower species diversity and higher presence of invasive species should be monitored more closely and corrective measures should be initiated at these sites to ensure fewer species do not continue to dominant these systems.

In regards to whether the studied wetlands are functioning to provide values of nutrient cycling and transformation, it does appear those wetlands studied are performing expected processes of immobilization (primarily in SP zones) and mineralization (primarily in PW zones). Immobilization is important in the process of retaining excessive and/or toxic nutrients, while mineralization is a process important to ensure available forms of nitrogen are present for plant uptake. Two important biogeochemical processes, denitrification and accumulation of organic matter, were not assessed in this study. Because increased rates of these processes are indicative of healthy wetland systems that are functioning to provide enhanced water quality benefits, further study of these parameters at these sites should provide insight into the sites' abilities to provide water quality functions. Future studies that are similar in methods to this study, and conducted in 10, 20, 30 or more years, at these sites would be benefical for comparison to the current findings. These comparisons would provide insight into the progression of wetland mitigation systems over a period of a few decades, rather than the typical monitoring period of 5 years.

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Appendix 1. Scientific name, 4 letter code, indicator status and common name of all species encountered in this study

Scientific Name *	Code	Ind †	Common Name †
Acalypha virginica L.	ACVI	FACU-	Three-Seeded Mercury
Acer negundo L.	ACNE	FAC+	Box Elder
Acer rubrum L.	ACRU	FAC	Red Maple
Achillea millefolium L.	ACMI	FACU	Common yarrow
Agrimonia gryposepala Wallr.	AGGR	FACU	Tall Hairy Groovebur
Agrimonia parviflora Aiton	AGPA	FAC	Small-Flower Groovebur
Agrostis alba L.	AGAL	FACW	Redtop
Alisma subcordatum Raf.	ALSU	OBL	Subcordate Water-plaintain
Ambrosia artemisiifolia L.	AMAR	FACU	Annual Ragweed
Apocynum cannabinum L.	APCA	FACU	Clasping-leaf Dogbane
Asclepias incarnata L.	ASIN	OBL	Swamp Milkweed
Aster laevis L.	ASLE	NI	Smooth Aster
Aster lateriflorus (L.) Britton	ASLT	FACW-	Calico Aster
Betula nigra L.	BENI	FACW	River Birch
Bidens cernua L.	BICE	OBL	Nodding Beggar-ticks
Bidens frondosa L.	BIFR	FACW	Devil's Beggar-ticks
Botrychium dissectum Spreng.	BODI	FAC	Cutleaf Grapefern
Bromus commutatus Schrader.	BRCO	NI	Hairy chess
Calystegia sepium (L.) R. Br.	CASE	FAC-	Hedge Bindweed
Carex cristatella Britton	CACR	FACW	Crested Sedge
Carex frankii Kunth	CAFR	OBL	Frank's Sedge
Carex glaucodea Tuck ex Olney	CAGL	NI	Sedge
Carex lupulina Muhl. ex. Willd.	CALP	OBL	Hop Sedge
Carex lurida Wahlenb.	CALR	OBL	Shallow Sedge
Carex tribuloides Wahlenb.	CATR	FACW+	Blunt Broom Sedge
Carex vulpinoidea Michx.	CAVU	OBL	Fox Sedge
Ceratophyllum demersum L.	CEDE	OBL	Common Hornwort
Chrysanthemum leacanthemum L.	CHLE	NI	Ox-eye Daisy
Cirsium vulgare (Savi) Tenore	CIVU	FACU-	Bull Thistle
Cornus amomum Mill.	COAM	FACW	Silky Dogwood
Crataegus viridis L.	CRVI	FACW	Green Hawthorn
Cyperus esculentas L.	CYES	FACW	Cyperus
Cyperus ferruginescens Boeck.	CYFE	FACW	Rusty Flatsedge
Daucus carota L.	DACA	NI	Queen Anne's Lace
Dichanthelium clandestinum (L.) Gould	DICL	FAC+	Deer-tongue Witchgrass
Dichanthelium sphaerocarpon (Elliott) Gould	DISP	FACU	Round-seed Panic Grass

Appendix 1. Continued.

Scientific Name *	Code	Ind †	Common Name †
Echinochloa crusgalli (L.) P. Beauv.	ECCR	FACU	Barnyard Grass
Eleocharis obtusa (Willd.) Schult.	ELOB	OBL	Blunt Spikerush
Eleocharis tenuis (Willd.) Schult.	ELTE	FACW+	Slender Spikerush
Elymus virginicus L.	ELVI	FACW-	Virginia Wild-rye
Epilobium hirsutum L.	EPHI	FACW	Great-hairy Willow-herb
Eragrostis capillaris (L.) Nees.	ERCA	NI	Lace grass
Erigiron strigosus Muhl. ex. Willd.	ERST	FACU+	Prairie Fleabane
Euonymus alatus (Thunb.) Siebold.	EUAL	NI	Winged burning bush
Euthamia graminifolia (L.) Nutt.	EUGR	FAC	Fragrant-golden-rod
Festuca rubra L.	FERU	FACU	Red Fescue
Fragaria vesca L.	FRVE	NI	Thin leaved wild strawberry
Fraxinus pennsylvanica Marshall	FRPE	FACW	Green Ash
Galium tinctorium L.	GATI	OBL	Stiff Marsh Bedstraw
Galium triflorum Michx.	GATR	FACU	Sweet-scent Bedstraw
Geum vernum (Raff.) Torr. & A. Gray	GUVE	FACU	Spring Avens
Helenium autumnale L.	HEAU	FACW+	Common Sneezeweed
Hypericum mutilum L.	HYMU	FACW	Slender St. John's-Wort
Impatiens capensis Meerb.	IMCA	FACW	Spotted Touch-me-not
Iris virginica L.	IRVI	OBL	Virginia Blueflag
Juncus acuminatus Michx.	JUAC	OBL	Taper-tip Rush
Juncus effusus L.	JUEF	FACW+	Soft Rush
Juncus tenuis Willd.	JUTE	FAC-	Slender Rush
Ludwigia leptocarpa (Nutt.) Hara	LULE	OBL	River Seedbox
Leersia oryzoides (L.) Sw.	LEOR	OBL	Rice Cutgrass
Lemna minor L.	LEMI	OBL	Lesser Duckweed
Lespedeza cuneata (Dumont) G. Don	LECU	NI	Chinese Bushclover
Lindera benzoin (L.) Blume	LIBE	FACW-	Northern Spicebush
Lindernia dubia (L.) Pennell	LIDU	OBL	False-pimpernel
Ludwigia palustris (L.) Elliott	LUPA	OBL	Marsh Seedbox
Lycopus americanus Muhl. ex. W. Barton	LYAM	OBL	American Bugleweed
Lysimachia nummularia L.	LYNU	OBL	Creeping Jennie
Malva moschata L.	MAMO	NI	Musk-mallow
Mentha spicata L.	MESP	FACW+	Spearmint
Najas minor All.	NAMI	OBL	Brittle Naiad
Panicum virgatum L.	PAVI	FAC	Switchgrass
Parthenocissus quinquefolia (L.) Planch.	PAQU	FACU	Virginia Creeper
Penthorum sedoides L.	PESE	OBL	Ditch-stonecrop

Appendix 1. Continued.

Scientific Name *	Code	Ind †	Common Name †
Phlaris arundinacea L.	PHAR	FACW+	Reed Canary Grass
Phleum pratense L.	PHPR	FACU	Timothy
Pilea pumila (L.) A. Gray	PIPU	FACW	Canada Clearweed
Plantago rugelii Decne.	PLRU	FACU	Black seed Plaintain
Poa pratensis L.	POPR	FACU	Kentucky Bluegrass
Polygonum amphibium L.	POAM	OBL	Water Smartweed
Polygonum hydropiperoides Michx.	POHY	OBL	Swamp Smartweed
Polygonum persicaria L.	POPE	FACW	Lady's Thumb
Polygonum sagittatum L.	POSA	OBL	Arrow-leaf Tearthumb
Populus deltoides W. Bartram ex Marshall	PODE	FAC	Eastern Cotton-wood
Portulaca oleracea L.	POOL		Common Purslane
Potamogeton foliosus Raf.	POFO	OBL	Leafy Pondweed
Potamogeton nodosus Poir.	POND	OBL	Longleaf Pondweed
Potentilla norvegica L.	PONV	FACU	Norwegian Cinquefoil
Prunella vulgaris L.	PRVU	FACU+	Heal-all
Quercus palustris Muenchh.	QUPA	FACW	Pin Oak
Quercus phellos L.	QUPH	FAC+	Willow Oak
Robinia pseudoacacia L.	ROPS	FACU-	Black Locust
Rosa multiflora Thunb.	ROMU	FACU	Multiflora Rose
Rosa palustris Marshall	ROPA	OBL	Swamp Rose
Rubus sp.	RUSP		
Rumex crispus L.	RUCR	FACU	Curly Dock
Sagittaria latifolia Willd.	SALA	OBL	Broad-leaf Arrow-head
Salix nigra Marshall	SANI	FACW+	Black Willow
Samolus parviflora Raf.	SAPA	OBL	Water Pimpernel
Scirpus atrovirens Willd.	SCAT	OBL	Green Bulrush
Scirpus validus Vahl.	SCVA	OBL	Soft-strem Bulrush
Setaria faberi R.A.W. Herrm.	SEFA	NI	Nodding foxtail-grass
Setaria glauca (L.) P. Beauv.	SEGL	FAC	Yellow Bristle Grass
Setaria viridis (L.) P. Beauv.	SEVI	NI	Green Foxtail-grass
Solidago canadensis L.	SOCA	FACU	Canada Golden-rod
Solidago flexicaulis L.	SOFL	FACU	Zigzag Golden-rod
Spartina pectinata Link	SPPE	OBL	Prairie Cordgrass
Spirodela polyrhiza (L.) Schleiden.	LEMA	OBL	Greater Duckweed
Taraxacum officinale Weber ex Wiggers	TAOF	FACU-	Common Dandelion
Toxicodendron radicans (L.) Kuntze	TORA	FAC	Poison Ivy
Trifolium pratense L.	TRPR	FACU-	Red Clover
Trifolium repens L.	TRRE	FACU-	White Clover

Appendix 1. Continued.

Scientific Name *	Code	Ind †	Common Name †
Typha angustifolia L.	TYAN	OBL	Narrow-leaf Cattail
Typha latifolia L.	TYLA	OBL	Broad-leaf Cattail
Ulmus rubra Muhl.	ULRU	FAC	Slippery Elm
Unk. Grass	UNGR		
Verbena hastata L.	VEHA	FACW+	Blue Vervain
Vernonia glauca (Walter) Trel.	VEGL	NI	Appalachian ironweed
Viburnum acerifolium L.	VIAC	NI	Flowering maple
Vitis sp.	VISP		
Wolffia punctata Griseb.	WOPU	OBL	Dotted Water-meal
Xanthium strumarium L.	XAST	FAC	Rough Cockle-bur

* Author follows Gleason and Cronquist (1991)

† Indicator status and common name for each species follows USFWS Region 1 National National List of Plant Species that Occur in Wetlands: Northeast (Region 1). For those species not listed by USFWS or assigned a status of NI by USFWS, the common name of species follows Gleason and Cronquist (1991).

Appendix 2. Importance values for all species encountered in study transects at each of the six sites. These values were used for multivariate ordination analysis. For ease of determining those species absent, those fields are left blank rather than entering an IV of 0.

Scientific Name	C *	Code	1	2	3	4	5	6
Acalypha virginica	0	ACVI				2.73	0.7	
Acer negundo	3	ACNE	0.31	0.3				
Acer rubrum	2	ACRU		1.02				
Achillea millefolium	1	ACMI	0.31	0.36			0.35	
Agrimonia gryposepala	3	AGGR		0.43				
Agrimonia parviflora	2	AGPA	1.49					
Agrostis alba	*	AGAL	0.59	0.72		0.29	6.52	
Alisma subcordatum	2	ALSU	0.99	1.38	1.15	7.91		1.71
Ambrosia artemisiifolia	0	AMAR			0.4	4.69		1.63
Apocynum cannabinum	1	APCA	0.42	0.36		0.29		
Asclepias incarnata	4	ASIN				0.56		0.59
Aster laevis	6	ASLE		2.17		1.41		3.55
Aster lateriflorus	2	ASLT	3.93	0.8	0.4	5.41		2.43
Betula nigra	9	BENI				0.22		
Bidens cernua	3	BICE		0.8	0.83	4.87	14.2	
Bidens frondosa	2	BIFR	0.31	0.3		2.45	0.53	2.22
Botrychium dissectum	3	BODI		0.3				
Bromus commutatus	*	BRCO					0.4	
Calystegia sepium	1	CASE						1.03
Carex cristatella	3	CACR			2.55	0.6		
Carex frankii	2	CAFR	1.66	0.8				1.19
Carex glaucodea	5	CAGL	0.31					
Carex lupulina	3	CALP		1.3				
Carex lurida	3	CALR	0.63	0.51				
Carex tribuloides	3	CATR	1.51	0.87			0.48	
Carex vulpinoidea	1	CAVU	0.9	2.39	0.47	1.67	1.63	8.9
Ceratopyllum demersum	2	CEDE	1.26		8.45			
Chrysanthemum leucanthemum	*	CHLE					0.4	
Cirsium vulgare	*	CIVU	1.49				4.18	1.8
Cornus amomum	2	COAM	0.68	0.51		0.29	1.19	
Craetegus viridis	*	CRVI	1.64	2.61				
Cyperus esculentas	0	CYES				3.01	0.35	1.42
Cyperus ferruginescens	4	CYFE				3.17		
Daucus carota	*	DACA	0.31		0.62	0.25	0.83	0.52
Dichanthelium clandestinum	2	DICL	2.14	1.23				

Appendix 2. Continued.

Scientific Name	C*	Code	1	2	3	4	5	6
Dichanthelium sphaerocarpon	4	DISP	0.37	1.02				
Echinochloa crusgalli	*	ECCR	0.42	16.5	0.36	8.17	1.8	1.34
Eleocharis obtusa	1	ELOB	5.7	8.46	3.24	7.68	6.39	
Eleocharis tenuis	9	ELTE						4.12
Elymus virginicus	3	ELVI						2.41
Epilobium hirsutum	*	EPHI					0.62	
Eragrostis capillaris	3	ERCA			0.51			
Erigiron strigosus	1	ERST	0.79		0.91	0.29		
Euonymus alatus	*	EUAL		0.32				
Euthamia graminifolia	2	EUGR	6.29	3.4		0.65	1.81	1.5
Festuca rubra	*	FERU	1.33				0.97	
Fragaria vesca	*	FRVE	0.31					
Fraxinus pennsylvanica	3	FRPE	2.34	0.3	0.87			
Galium tinctorium	4	GATI		1.99				0.52
Galium triflorum	4	GATR		1.37				
Geum vernum	2	GUVE	0.37					3
Helenium autumnale	4	HEAU						4.12
Hypericum mutilum	3	HYMU					0.35	
Impatiens capensis	3	IMCA		1.49				
Iris virginica	6	IRVI	0.59					
Juncus acuminatus	4	JUAC		0.87				
Juncus effusus	1	JUEF	5.02	0.72	0.4		0.44	4.09
Juncus tenuis	1	JUTE	0.37	2.24	0.43	0.29	1.67	1.11
Leersia oryzoides	1	LEOR	1.55	4.59	10.8	5.6	9.25	8.05
Lemna minor	3	LEMI	24.4	1.24	13	2.36	3.66	5.05
Lespedeza cuniatum	*	LECU					0.4	
Lindera benzoin	5	LIBE				0.29		
Lindernia dubia	2	LIDU				0.66		
Ludwigia leptocarpa	*	LULE						8.08
Ludwigia palustris	3	LUPA		2.18	1.38	6.95	6.92	1.97
Lycopus americanus	3	LYAM	1.9	0.36		0.37		0.52
Lysimachia nummularia	*	LYNU	4.28					
Malva moschata	*	MAMO				0.22		
Mentha spicata	*	MESP				0.37		
Najas minor	*	NAMI		3.28		1.56		
Panicum virgatum	4	PAVI				3.68	2.07	0.91
Parthenocissus quinquefolia	2	PAQU	0.37	0.36				

Appendix 2. Continued.

Scientific Name	C *	Code	1	2	3	4	5	6
Penthorum sedoides	2	PESE			0.4	0.29		1.34
Phlaris arundinacea	0	PHAR		0.43	8.42		8.46	
Phleum pratense	*	PHPR		0.88			1.23	
Pilea pumila	2	PIPU		1.17				
Plantago rugelii	0	PLRU					0.44	
Poa pratensis	*	POPR	5	8.84	0.94	1.25	3.35	2.09
Polygonum amphibium	4	POCO			1.62		0.66	
Polygonum hydropiperoides	6	POHY		0.33		1.91	1.14	2.14
Polygonum persicaria	*	POPE		0.43				
Polygonum sagittatum	2	POSA					0.48	
Populus deltoides	3	PODE				0.37		
Portulaca oleracea	*	POOL						0.59
Potamogeton foliosus	2	POFO	2.27	0.87	4.31	0.97		
Potamogeton nodosus	3	POND	1.49	4.08	0.92	5.82		
Potentilla norvegica	1	PONV	0.31			0.29	0.48	
Prunella vulgaris	0	PRVU	0.31					
Quercus palustris	5	QUPA	0.31	0.36			0.35	
Quercus phellos	*	QUPH			0.4			
Robinia pseudoacacia	0	ROPS					0.57	
Rosa multiflora	*	ROMU	0.37				0.48	0.75
Rosa palustris	5	ROPA	2.92					0.59
Rubus sp.		RUSP						0.75
Rumex crispus	*	RUCR			0.4	1.59	1.05	
Sagittaria latifolia	1	SALA		1.02	0.55			
Salix nigra	2	SANI			1.86			
Samolus parviflora	4	SAPA						0.52
Scirpus atrovirens	1	SCAT	3.55	0.36	0.4			
Scirpus validus	2	SCVA	0.59	0.82	1.54	3.05	1.02	1.06
Setaria faberi	*	SEFA		1.53				
Setaria glauca	*	SEGL		1.33	0.33	1.27		
Setaria viridis	*	SEVI				0.69		
Solidago canadensis	1	SOCA	1.62	1.9	0.62	0.81	1.58	5.02
Solidago flexicaulis	5	SOFL			0.62		3	
Spartina pectinata	5	SPPE						0.75
Spirodela polyrhiza	5	LEMA		0.36				
Taraxacum officinale	*	TAOF		0.36			0.4	
Toxicodendron radicans	1	TORA	0.9					

Appendix 2. Continued.

Scientific Name	C *	Code	1	2	3	4	5	6
Trifolium pratense	*	TRPR		0.43	0.4			
Trifolium repens	*	TRRE		1.31		0.78	0.4	0.45
Typha angustifolia	*	TYAN						3.06
Typha latifolia	1	TYLA	1.07	0.87	2.89	1.06	6.44	6.58
Ulmus rubra	3	ULRU			0.47			
Unk. Grass		UNGR					0.4	
Verbena hastata	4	VEHA		0.43				
Vernonia glauca	2	VEGL	1.11	0.51				
Viburnum acerifolium	6	VIAC		0.36				
Vitis sp.		VISP	0.85					
Wolffia punctata	6	WOPU		1.16	26.1			0.52
Xanthium strumarium	*	XAST				0.94		

* Coefficient of Conservatism (C of C) designation follows Andreas et al. (2004). Non-native species are identifed by an *. Non-native and/or invasive species are designated by a 0. All other designations are described in Table 2.

Appendix 3. Checklist of vegetation and associated codes present at all sites. An 'X' represents presence of the species at a particular site.

Species	Code	1	2	3	4	5	6
Acalypha virginica	ACVI				X	X	
Acer negundo	ACNE	X	X				
Acer rubrum	ACRU		X				
Achillea millefolium	ACMI	X	X			X	
Agrimonia gryposepala	AGGR		X				
Agrimonia parviflora	AGPA	X					
Agrostis alba	AGAL	X	X		X	X	
Alisma subcordatum	ALSU	X	X	X	X		X
Ambrosia artemisiifolia	AMAR			X	X		X
Apocynum cannabinum	APCA	X	X		X		
Asclepias incarnata	ASIN				X		X
Aster laevis	ASLE		X		X		X
Aster lateriflorus	ASLT	X	X	X	X		X
Betula nigra	BENI				X		
Bidens cernua	BICE		X	X	X	X	
Bidens frondosa	BIFR	X	X		X	X	X
Botrychium dissectum	BODI		X				
Bromus commutatus	BRCO					X	
Calystegia sepium	CASE						X
Carex cristatella	CACR			X	X		
Carex frankii	CAFR	X	X				X
Carex glaucodea	CAGL	X					
Carex lupulina	CALP		X				
Carex lurida	CALR	X	X				
Carex tribuloides	CATR	X	X			X	
Carex vulpinoidea	CAVU	X		X	X	X	X
Ceratopyllum demersum	CEDE	X		X			
Chrysanthemum leacanthemum	CHLE					X	
Cirsium vulgare	CIVU	X	X			X	X
Cornus amomum	COAM	X	X		X	X	
Crataegus viridis	CRVI	X					
Cyperus esculentas	CYES				X	X	X
Cyperus ferruginescens	CYFE				X		
Daucus carota	DACA	X	X	X	X	X	X
Dichanthelium clandestinum	DICL	X	X				
Dichanthelium sphaerocarpon	DISP	X	X				

Appendix 3. Continued.

Species	Code	1	2	3	4	5	6
Echinochloa crusgalli	ECCR	X	X	X	X	X	X
Eleocharis obtusa	ELOB	X	X	X	X	X	X
Eleocharis tenuis	ELTE						X
Elymus virginicus	ELVI						X
Epilobium hirsutum	EPHI					X	
Eragrostis capillaris	ERCA			X			
Erigiron strigosus	ERST	X		X	X		
Euonymus alatus	EUAL		X				
Euthamia graminifolia	SOGR	X	X		X	X	X
Festuca rubra	FERU	X				X	
Fragaria vesca	FRVE	X					
Fraxinus pennsylvanica	FRPE	X	X	X			
Galium tinctorium	GATI		X				X
Galium triflorum	GATR		X				
Geum vernum	GUVE	X					X
Helenium autumnale	HEAU						X
Hypericum mutilum	HYMU					X	
Impatiens capensis	IMCA		X				
Iris virginica	IRVI	X					
Juncus acuminatus	JUAC		X				
Juncus effusus	JUEF	X	X	X		X	X
Juncus tenuis	JUTE	X	X	X	X	X	X
Leersia oryzoides	LEOR	X	X	X	X	X	X
Lemna minor	LEMI	X	X	X	X	X	X
Lespedeza cuniatum	LECU					X	
Lindera benzoin	LIBE				X		
Lindernia dubia	LIDU				X		
Ludwigia leptocarpa	LULE						X
Ludwigia palustris	LUPA		X	X	X	X	X
Lycopus americanus	LYAM	X	X		X		X
Lysimachia nummularia	LYNU	X					
Malva moschata	MAMO				X		
Mentha spicata	MESP				X		
Najas minor	NAMI		X		X		
Panicum virgatum	PAVI				X	X	X
Parthenocissus quinquefolia	PAQU	X	X				

Appendix 3. Continued.

Species	Code	1	2	3	4	5	6
Penthorum sedoides	PESE			X	X		X
Phalaris arundinacea	PHAR		X	X		X	
Phleum pratense	PHPR		X			X	
Pilea pumila	PIPU		X				
Plantago rugelii	PLRU					X	
Poa pratensis	POPR	X	X	X	X	X	X
Polygonum amphibium	POAM			X		X	
Polygonum hydropiperoides	POHY		X		X	X	X
Polygonum persicaria	POPE		X				
Polygonum sagittatum	POSA					X	
Populus deltoides	PODE				X		
Portulaca oleracea	POSP					X	X
Potamogeton foliosus	POFO	X	X	X	X		
Potamogeton nodosus	POND	X	X	X	X		
Potentilla norvegica	PONV	X			X		
Prunella vulgaris	PRVU	X					
Quercus palustris	QUPA	X	X			X	
Quercus phellos	QUPH			X			
Robinia pseudoacacia	ROPS					X	
Rosa multiflora	ROMU	X				X	X
Rosa palustris	ROPA	X					X
Rubus sp.	RUSP						X
Rumex crispus	RUCR			X	X	X	
Sagittaria latifolia	SALA		X	X			
Salix nigra	SANI			X			
Samolus parviflora	SAPA						X
Scirpus atrovirens	SCAT	X	X	X			
Scirpus validus	SCVA	X	X	X	X	X	X
Setaria faberi	SEFA		X				
Setaria glauca	SEGL		X	X	X		
Setaria viridis	SEVI				X		
Solidago canadensis	SOCA	X	X	X	X	X	X
Solidago flexicaulis	SOFL			X		X	
Spartina pectinata	SPPE						X
Spirodela polyrhiza	SPPO		X				
Taraxacum officinale	TAOF		X			X	
Toxicodendron radicans	TORA	X					

Appendix 3. Continued.

Species	Code	1	2	3	4	5	6
Trifolium pratense	TRPR		X	X			
Trifolium repens	TRRE		X		X	X	X
Typha angustifolia	TYAN						X
Typha latifolia	TYLA	X	X	X	X	X	X
Ulmus rubra	ULRU			X			
Unk. Grass	UNGR					X	
Verbena hastata	VEHA		X				
Vernonia glauca	VEGL	X	X				
Viburnum acerifolium	VIAC		X				
Vitis sp.	VISP	X					
Wolffia punctata	WOPU		X	X			X
Xanthium strumarium	XAST				X		

Appendix 4. Importance values (IV) for species at each of the six study sites in each of the three zones of old field, seasonally pooled and permanently pooled wetland. IV for each species is based on the sum of relative cover and relative frequency (values not shown).

HONDA SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Acer negundo				0.12	0.02	0.45			
Achillea millefolium	1.25	0.25	1.58						
Agrimonia parviflora	10	0.25	3.86	0.6	0.05	1.13			
Agrostis alba				0.71	0.02	0.83			
Alisma subcordatum				0.36	0.05	0.98	1	0.2	3.79
Apocynum cannabinum	3.75	0.25	2.23						
Aster lateriflorus	10.3	0.5	5.17	1.81	0.17	3.78	1	0.2	3.79
Bidens frondosa				0.12	0.02	0.45			
Carex frankii				1.9	0.07	2.34			
Carex glaucodea				0.12	0.02	0.45			
Carex lurida				0.12	0.02	0.45			
Carex tribuloides	10	0.5	5.11	0.07	0.05	0.8			
Carex vulpinoidea				0.83	0.05	1.28			
Ceratophyllum demersum				0.14	0.05	0.84	3	0.4	8.25
Cirsium vulgare	9	0.75	6.1	0.12	0.02	0.45			
Cornus amomum				0.36	0.05	0.98			
Crataegus viridis	3.75	0.5	3.48	0.4	0.07	1.39			
Daucus carota	1.25	0.25	1.58						
Dichanthelium clandestinum				2.38	0.1	3.02			
Dichanthelium sphaerocarpon	3.75	0.5	3.48						
Echinochloa crusgalli				0.36	0.02	0.6			
Eleocharis obtusa				4.76	0.14	5.29	19	0.4	18.9
Erigiron strigosus	6.25	0.5	4.13						
Euthamia graminifolia				5	0.24	6.94	1	0.2	3.79
Festuca rubra	7.5	0.25	3.21	0.48	0.05	1.06			
Fragaria vesca									
Fraxinus pennsylvanica	10	0.5	5.11	0.36	0.05	0.98	8	0.2	8.46
Geum vernum	2.5	0.25	1.9						
Iris virginica				0.71	0.02	0.83			
Juncus effusus				6.31	0.14	6.27	5	0.2	6.46
Juncus tenuis	2.5	0.25	1.9						

Appendix 4. Continued.

HONDA SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Leersia oryzoides				1.67	0.07	2.19			
Lemna minor	10	0.25	3.86	26.1	0.88	30.5	18	0.8	24.5
Lycopus americanus	3.75	0.25	2.23	0.95	0.1	2.11			
Lysimachia nummularia				5.83	0.1	5.22	5	0.2	6.46
Parthenocissus quinquifolia	2.5	0.25	1.9						
Poa pratensis	38.8	0.75	13.9	4.29	0.05	3.48			
Potamogeton foliosus				1.07	0.12	2.56	4	0.2	5.79
Potamogeton nodosus				0.24	0.02	0.53	10	0.2	9.79
Potentilla norvegica	1.25	0.25	1.58						
Prunella vulgaris	1.25	0.25	1.58						
Quercus palustris	1.25	0.25	1.58						
Rosa multiflora	2.5	0.25	1.9	3.81	0.07	3.55			
Rosa palustris	2.5	0.25	1.9						
Scirpus atrovirens				4.31	0.14	5			
Scirpus validus	7.5	0.25	3.21						
Solidago canadensis	25	0.5	9.02						
Toxicondendron radicans	8.75	0.5	4.78						
Typha latifolia				1.19	0.05	1.51			
Vernonia glauca	2.5	0.25	1.9	0.48	0.05	1.06			
Vitis sp.	2.5	0.25	1.9	0.48	0.02	0.68			
MEDALLION SITE									
Acer negundo				0.04	0.04	0.43			
Acer rubrum	0.5	0.25	1.74	0.39	0.09	1			
Achillea millefolium	1.25	0.25	1.99						
Agrimonia gryposepala				0.43	0.04	0.62			
Agrostis alba				0.43	0.09	1.02			
Alisma subcordatum				1.3	0.04	1.04	6.25	0.25	5.38
Apocynum cannabinum				0.22	0.04	0.51			
Aster laevis	2.5	0.5	3.99	1.74	0.13	2.07			
Aster lateriflorus	2.5	0.25	2.43	0.22	0.04	0.51			
Bidens cernua				0.65	0.09	1.13			
Bidens frondosa				0.04	0.04	0.43			
Botrychium dissectum				0.04	0.04	0.43			
Carex frankii				0.65	0.09	1.13			

Appendix 4. Continued.

MEDALLION SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Carex lupulina	2.5	0.25	2.43	0.87	0.09	1.24			
Carex lurida				0.65	0.04	0.72			
Carex tribuloides				0.87	0.09	1.24			
Cirsium vulgare	5	0.5	4.85	1.09	0.17	2.16			
Cornus amomum				0.65	0.04	0.72			
Daucus carota	15	0.75	9.87	0.87	0.09	1.24			
Dichanthelium clandestinum	3.75	0.5	4.42	0.43	0.04	0.62			
Dichanthelium sphaerocarpon				0.48	0.13	1.45			
Echinochloa crusgalli	28.8	0.5	13.1	33.5	0.43	20.4			
Eleocharis obtusa				13.5	0.35	9.81	12.5	0.75	13.4
Euonymus alatus				0.09	0.04	0.45			
Euthamia graminifolia	10	0.75	8.14	2.35	0.17	2.77			
Fraxinus pennsylvanica				0.04	0.04	0.43			
Galium tinctorium				0.78	0.26	2.82			
Galium triflorum	1.25	0.25	1.99	0.43	0.13	1.43			
Impatiens capensis				1	0.17	2.11			
Juncus acuminatus				0.87	0.09	1.24			
Juncus effusus				0.43	0.09	1.02			
Juncus tenuis	3.75	0.5	4.42	0.87	0.17	2.05			
Leersia oryzoides				5.43	0.26	5.08	12.5	0.25	8.13
Lemna minor							11.3	0.5	10.2
Ludwigia palustris				2.17	0.09	1.87	5	0.5	7.46
Lycopus americanus				0.22	0.04	0.51			
Najas minor				0.65	0.04	0.72	32.5	0.75	22.2
Parthenocissus quinquefolia				0.22	0.04	0.51			
Phalaris arundinacea				0.43	0.04	0.62			
Phleum pratense				1.74	0.04	1.25			
Pilea pumila				0.91	0.13	1.66			
Poa pratensis	48.8	1	23.1	10	0.22	6.9			
Polygonum hydropiperoides				0.13	0.04	0.47			
Polygonum persicaria				0.43	0.04	0.62			
Potamogeton foliosus				0.43	0.04	0.62	2.5	0.25	3.73
Potamogeton nodosus				3.04	0.09	2.29	22.5	1	20.4
Quercus palustris	1.25	0.25	1.99						

Appendix 4. Continued.

MEDALLION SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Sagittaria latifolia				2.17	0.04	1.46			
Scirpus atrovirens				0.22	0.04	0.51			
Scirpus validus	0.5	0.25	1.74	0.65	0.04	0.72			
Setaria faberi	1.25	0.25	1.99	0.91	0.13	1.66			
Setaria glauca				0.52	0.17	1.88			
Solidago canadensis	2.5	0.25	2.43	3.48	0.04	2.1			
Spirodela polyrhiza							1.25	0.25	3.18
Taraxacum officinale	1.25	0.25	1.99						
Trifolium pratense				0.43	0.04	0.62			
Trifolium repens	12.5	0.5	7.44						
Typha latifolia				0.87	0.09	1.24			
Verbena hastata				0.43	0.04	0.62			
Vernonia glauca				0.65	0.04	0.72			
Virburnum acerifolium				0.22	0.04	0.51			
Wolffia punctata				0.43	0.04	0.62	7.5	0.25	5.93
NEW ALBANY SITE									
Alisma subcordatum				0.89	0.11	1.67			
Ambrosia artemisiifolia	5	0.5	4.4						
Aster lateriflorus				0.36	0.04	0.57			
Bidens cernua				0.89	0.07	1.2			
Carex cristatella	30	1	13.9	3.93	0.07	2.07			
Carex vulpinoidea				0.71	0.04	0.68			
Ceratophyllum demersum				22.9	0.32	10.8	2	0.2	3.72
Daucus carota	20	0.5	8.24						
Echinochloa crusgalli				0.18	0.04	0.52			
Eleocharis obtusa				5	0.18	3.79	3.5	0.1	2.72
Eragrostis capillaris				0.89	0.04	0.73			
Erigiron strigosus	17.5	1	10.7						
Fraxinus pennsylvanica				0.36	0.04	0.57	2	0.1	2.2
Juncus effusus				0.36	0.04	0.57			
Juncus tenuis	7.5	0.5	5.04						
Leersia oryzoides	10	0.5	5.68	34.3	0.36	14.5			
Lemna minor				14.5	0.64	12.6	13.5	1	19.8

Appendix 4. Continued.

NEW ALBANY SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Ludwigia palustris				1.96	0.11	1.98			
Penthorum sedoides				0.36	0.04	0.57			
Phalaris arundinacea	35	0.5	12.1	14.1	0.39	9.23	6	0.2	5.09
Poa pratensis	20	1	11.4						
Polygonum amphibium				1.61	0.14	2.35			
Potamogeton foliosus				2.5	0.18	3.07	12	0.4	10.2
Potamogeton nodosus				2.86	0.04	1.29			
Quercus phellos							1	0.1	1.86
Rumex crispus	5	0.5	4.4						
Sagittaria latifolia				1.07	0.04	0.78			
Salix nigra				3.21	0.07	1.86	3	0.1	2.55
Scirpus atrovirens				0.36	0.04	0.57			
Scirpus validus				4.29	0.07	2.17			
Setaria glauca	0.5	0.5	3.25						
Solidago canadensis	20	0.5	8.24						
Solidago flexicaulis	20	0.5	8.24						
Trifolium pratense	5	0.5	4.4						
Typha latifolia				4.82	0.11	2.8	8	0.1	4.26
Ulmus rubra				0.71	0.04	0.68			
Wolffia punctata				51.4	0.57	22.3	94.5	1	47.6
ODOT SITE									
Acalypha virginica	3.33	0.33	3.56	3.91	0.23	2.84			
Agrostis alba	3.33	0.33	3.56						
Alisma subcordatum				16.6	0.58	9.21			
Ambrosia artemisiifolia	13.3	0.67	9.26	4.97	0.42	4.61			
Apocynum cannabinum	3.33	0.33	3.56						
Asclepias incarnata				1.41	0.03	0.65			
Aster laevis	33.3	1	18.1						
Aster lateriflorus				11.6	0.39	6.29			
Betula nigra				0.03	0.03	0.25			
Bidens cernua				9.44	0.39	5.67			
Bidens frondosa	3.33	0.33	3.56	2.81	0.23	2.52			
Carex cristatella				1.56	0.03	0.7			

Appendix 4. Continued.

ODOT SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Carex vulpinoidea				2.5	0.16	1.95			
Cornus amomum				0.31	0.03	0.33			
Cyperus esculentas				7.03	0.19	3.5			
Cyperus ferruginescens				5.16	0.29	3.69			
Daucus carota				0.16	0.03	0.29			
Echinochloa crusgalli				18.1	0.52	9.16	2	0.2	5.1
Eleocharis obtusa				19.8	0.42	8.93			
Erigiron strigosus	3.33	0.33	3.56						
Euthamia graminifolia	6.67	0.33	4.63	0.31	0.03	0.33			
Juncus tenuis				0.31	0.03	0.33			
Leersia oryzoides				12.3	0.39	6.51			
Lemna minor				0.03	0.03	0.25	28	1	36.7
Lindera benzoin				0.31	0.03	0.33			
Lindernia dubia				0.97	0.06	0.77			
Ludwigia palustris				16.9	0.42	8.08			
Lycopus americanus	6.67	0.33	4.63						
Malva moschata				0.03	0.03	0.25			
Mentha spicata				0.63	0.03	0.43			
Najas minor				0.31	0.03	0.33	22	0.4	21.4
Panicum virgatum	48.3	1	22.9	5.16	0.1	2.23			
Penthorum sedoides				0.31	0.03	0.33			
Poa pratensis	10	0.33	5.69	1.56	0.06	0.94			
Polygonum hydropiperoides				0.94	0.26	2.22			
Populus deltoides				0.63	0.03	0.43			
Potamogeton foliosus							10	0.2	10.1
Potamogeton nodosus				11.3	0.23	4.97	18	0.8	26.6
Potentilla norvegica				0.31	0.03	0.33			
Rumex crispus	3.33	0.33	3.56	1.88	0.13	1.52			
Scirpus validus				7.19	0.19	3.55			
Setaria glauca				1.72	0.13	1.47			
Setaria viridis				1.09	0.06	0.81			
Solidago canadensis	13.3	0.33	6.76	0.31	0.03	0.33			
Trifolium repens	5	0.67	6.6	0.16	0.03	0.29			
Typha latifolia				1.72	0.1	1.23			
Xanthium strumarium				0.41	0.13	1.09			

Appendix 4. Continued.

ODOT WCA SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Acalypha virginica	1.67	0.33	1.91	0.21	0.04	0.5			
Achillea millefolium	1.67	0.33	1.91						
Agrostis alba	30	1	11	12.5	0.29	6.86			
Bidens cernua				35.8	0.63	17.4	23	0.6	14.8
Bidens frondosa	8.33	0.33	3.31						
Bromus commutatus				0.42	0.04	0.56			
Carex vulpinoidea				1.88	0.17	2.32			
Carex tribuloides				0.83	0.04	0.69			
Chrysanthemum leucanthemum	3.33	0.33	2.26						
Cirsium vulgare	13.3	0.67	5.92	7.92	0.21	4.59			
Cornus amomum				4.17	0.04	1.7			
Cyperus esculentas				0.21	0.04	0.5			
Daucus carota	6.67	0.33	2.96	0.21	0.04	0.5			
Echinochloa crusgalli				2.71	0.17	2.58			
Eleocharis obtusa				12.5	0.42	8.17	8	0.2	5
Epilobium hirsutum				1.46	0.04	0.88			
Euthamia graminifolia	26.7	0.67	8.72	0.83	0.04	0.69			
Festuca rubra	6.67	0.33	2.96	0.83	0.04	0.69			
Hypericum mutilum				0.21	0.04	0.5			
Juncus effusus				0.63	0.04	0.63			
Juncus tenuis	3.33	0.67	3.82	1.67	0.08	1.38			
Leersia oryzoides				11.9	0.46	8.42	41	1	25.3
Lemna minor				3.13	0.08	1.82	40	0.4	16.2
Lespedeza cuniatum	3.33	0.33	2.26						
Ludwigia palustris				7.08	0.21	4.34	60	0.8	27.2
Panicum virgatum	18.3	0.67	6.97	1.67	0.08	1.38			
Phalaris arundinaceae				17.9	0.42	9.82	22	0.4	11.6
Phleum pratense	16.7	0.33	5.06	0.83	0.04	0.69			
Plantago rugelii	5	0.33	2.61						
Poa pratensis	36.7	1	12.4	2.5	0.13	2.07			
Polygonum amphibium				1.67	0.04	0.94			
Polygonum hydropiperoides				1.04	0.13	1.63			
Polygonum sagittatum				0.83	0.04	0.69			
Potentilla norvegica	6.67	0.33	2.96						

Appendix 4. Continued.

ODOT WCA SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Quercus palustris	1.67	0.33	1.91						
Robinia pseudoacacia	10	0.33	3.66						
Rosa multiflora	6.67	0.33	2.96						
Rumex crispus	1.67	0.33	1.91	0.42	0.08	1			
Scirpus validus				3.33	0.04	1.45			
Solidago canadensis	23.3	0.67	8.02	0.21	0.04	0.5			
Solidago flexicaulis				8.33	0.17	4.28			
Taraxacum officinale	3.33	0.33	2.26						
Trifolium repens	3.33	0.33	2.26						
Typha latifolia				18.8	0.33	9.19			
Unk grass				0.42	0.04	0.56			
ROSS SITE									
Alisma subcordatum				2.5	0.3	2.86			
Ambrosia artemisiifolia	5	0.75	5.38						
Asclepias incarnata				1	0.1	0.99			
Aster lateriflorus				10	0.2	3.85			
Aster laevis	28.8	1	13.1						
Bidens frondosa	3.75	0.5	3.7	1.5	0.2	1.87			
Calystegia sepium	2.5	0.5	3.37						
Carex frankii				2	0.2	1.98			
Carex vulpinoidea	12.5	0.75	7.38	24	0.7	10.9			
Cirsium vulgare	5.25	0.5	4.1	1	0.1	0.99			
Cyperus esculentas				3.5	0.2	2.33			
Daucus carota	1.23	0.25	1.68						
Echinochloa crusgalli				1	0.1	0.99	5	0.25	7.66
Eleocharis obtusa							12.5	0.25	12.3
Eleocharis tenuis				13	0.2	4.56			
Elymus virginicus	15	0.5	6.69	1	0.1	0.99			
Euthamia graminifolia	10	0.5	5.36						
Galium tinctorium				0.5	0.1	0.87			
Geum vernum	20	1	10.7						
Helenium autumnale				18	0.3	6.48			
Juncus effusus				15	0.4	6.54			

Appendix 4. Continued.

ROSS SITE	OF			SP			PW		
Species	C *	Fr †	IV ‡	C	Fr	IV	C	Fr	IV
Juncus tenuis	2.5	0.25	2.02	0.5	0.1	0.87			
Ludwigia leptocarpa				35	0.6	12.7			
Leersia oryzoides				32	0.7	12.8			
Lemna minor				4.3	0.4	4.04	14	1	26.9
Ludwigia palustris				7	0.2	3.15			
Lycopus americanus	1.25	0.25	1.68						
Panicum virgatum	7.5	0.25	3.35						
Penthorum sedoides				3	0.2	2.22			
Poa pratensis	12.5	0.75	7.38						
Polygonum hydropiperoides				2.5	0.4	3.61			
Portulaca oleracea				1	0.1	0.99			
Rosa multiflora	5	0.25	2.68						
Rosa palustris				1	0.1	0.99			
Rubus sp.	5	0.25	2.68						
Samolus parviflorus				0.5	0.1	0.87			
Scirpus validus							10	0.25	10.8
Solidago canadensis	50	0.75	17.4	1	0.1	0.99			
Spartina pectinata				2	0.1	1.23			
Trifolium repens	0.25	0.25	1.42						
Typha angustifolia				10	0.1	3.1	10	0.25	10.8
Typha latifolia				20	0.2	6.19	27.5	0.5	26.2
Wolffia punctata							1.25	0.25	5.32

* Absolute cover; † Absolute frequency; ‡ Importance Value

Appendix 5. Environmental data collected from the upper 5 cm of soil at each of the six study sites. Because differences among the same zones across different transects were significant, means of this data were calculated for further analysis.

Site	Tr *	Zone†	% Moist	Pre NO_3^- µg/g	Pre NH_4^+ µg/g	Pt NO_3^- µg/g	Pt NH_4^+ µg/g	N Min µg/g ‡	Nit µg/g ‡‡
1	1	SP	19.19	0.34	2.24	0.87	2.07	0.36	0.53
		PW	31.46	1.51	9.20	1.97	4.41	-4.33	0.46
	2	SP	22.26	0.22	2.77	0.10	2.33	-0.56	-0.12
		PW	24.65	0.00	3.33	0.21	4.62	1.50	0.21
	3	SP	32.81	0.00	2.92	0.00	7.26	4.33	0.00
		PW	34.04	0.14	4.59	0.24	7.54	3.05	0.10
	4	SP	36.70	0.16	8.06	0.24	15.06	7.09	0.09
		PW	40.90	0.46	6.59	0.26	15.28	8.49	-0.20
	1	OF	18.20	0.73	10.39	0.50	3.10	-7.52	-0.23
	2	OF	29.35	0.26	4.13	0.00	9.62	5.23	-0.26
	3	OF	17.00	0.40	6.08	0.73	5.75	0.01	0.33
	4	OF	21.00	0.53	12.98	0.56	9.89	-3.06	0.03
2	1	SP	24.68	1.09	1.21	0.61	0.91	-0.77	-0.48
		PW	25.34	0.00	2.56	0.00	0.99	-1.57	0.00
	2	SP	20.40	0.12	3.02	0.00	0.86	-2.28	-0.12
		PW	33.90	0.00	0.61	0.00	1.16	0.55	0.00
	3	SP	22.90	0.46	1.74	0.84	1.92	0.56	0.38
		PW	26.67	0.00	1.06	0.11	1.48	0.53	0.11
	4	SP	19.55	4.88	1.46	0.33	1.54	-4.47	-4.55
		PW	25.24	0.00	0.72	0.00	1.57	0.85	0.00
	1	OF	21.61	1.13	0.90	0.38	0.89	-0.76	-0.75
3	1	SP	24.88	0.00	13.83	0.52	0.26	-13.04	0.52
		PW	31.90	0.00	0.00	0.51	1.27	1.77	0.51
	2	SP	23.11	4.84	3.85	3.21	11.42	5.95	-1.63
	1	OF	17.00	0.55	4.59	0.00	1.45	-3.69	-0.55
4	1	SP	27.03	1.07	10.74	0.00	3.56	-8.25	-1.07
		PW	28.06	0.23	13.72	5.37	3.45	-5.12	5.14
	2	SP	21.10	1.11	9.97	1.82	9.12	-0.14	0.72
		PW	29.30	1.07	15.80	0.36	5.36	-11.14	-0.71
	3	SP	25.17	0.25	6.36	0.00	2.97	-3.64	-0.25
		PW	33.54	4.75	10.68	5.49	3.53	-6.40	0.75
	1	OF	24.72	0.45	9.19	5.82	3.91	0.09	5.36
	2	OF	26.20	0.86	4.53	0.23	6.35	1.19	-0.63

Appendix 5. Continued.

Site	Tr *	Zone†	% Moist	Pre NO_3^- µg/g	Pre NH_4^+ µg/g	Pt NO_3^- µg/g	Pt NH_4^+ µg/g	N Min µg/g ‡	Nit µg/g ‡‡
	3	OF	26.39	0.86	7.90	5.69	8.24	5.16	4.82
5	1	SP	23.67	0.13	2.87	2.60	4.43	4.03	2.47
		PW	26.58	0.00	5.62	0.00	4.46	-1.17	0.00
	2	SP	21.87	0.37	1.75	2.08	5.32	5.29	1.71
		PW	25.83	0.00	2.12	1.22	4.99	4.09	1.22
	3	SP	23.52	2.08	1.27	2.28	2.28	1.21	0.20
	1	OF	18.20	0.67	3.85	5.76	3.63	4.88	5.09
6	1	SP	23.81	1.04	1.17	0.95	1.43	0.18	-0.08
		PW	26.01	0.00	1.31	0.13	1.70	0.51	0.13
	2	SP	25.02	0.00	2.17	0.23	1.83	-0.10	0.23
	3	SP	23.35	3.94	0.98	0.00	2.00	-2.93	-3.94
		PW	29.23	0.00	1.63	0.11	3.20	1.69	0.11
	4	SP	23.12	0.88	2.53	0.00	0.91	-2.50	-0.88
		PW	27.35	0.00	1.58	0.00	1.92	0.34	0.00
	1	OF	22.00	0.92	2.20	0.53	1.47	-1.12	-0.39

*, Transect; † Zones: SP (seasonally pooled); PW (Permanent pooled wetland; OF (Old field); ‡ Nitrogen mineralization; ‡‡ Nitrification

Desiree Lawson Hann

Education

Marshall University — December 2004
Huntington, WV
M.S. Biological Sciences

Marshall University — May 2000
Huntington, WV
B.S. Biological Sciences
- John Marshall Scholar
- Magna cum Laude (3.70 GPA)
- Minor in Chemistry
- Completed all interdisciplinary Yeager Scholar Honors Courses

Awards Received

John Marshall Scholarship during undergraduate years of 1995 -2000.

Marshall University's Dean's List – 1995 – 2000.

Work Experience

US Army Corps of Engineers — July 2000 – Present
- Huntington, WV

Regulatory Specialist, Biologist
- Processed hundreds of applications and ensured compliance with Section 404 of the Clean Water Act;
- Reviews complicated projects and has written numerous complex decision documents including Statement of Findings, Environmental Assessments and determinations of compliance with Section 404(b)(1) Guidelines;
- Conducts routine delineations of waters and verifies the presence of jurisdictional waters of the US on proposed development sites;
- Has reviewed numerous on and off-site wetland mitigation plans;
- Investigates allegations of unauthorized work in waters of the US;
- Conducts pre-application meetings with potential applicants to discuss avoidance and minimization of impacts to waters of the US.

Marshall University — August 2000 – May 2002
Huntington, WV

Graduate Teaching Assistant
- Instructed introductory Biology laboratory courses to science and non-science majors;
- Maintained grade records for course assignments, quizzes and papers;
- Conducted set-up of all introductory biology laboratories; and
- Worked as an assistant to select professors as assigned.

Cracker Barrel — November 1998 – December 2000
Barboursville, WV
Server

- Worked as a server

Lowe's Home Improvement — June 1995 – November 1998
Barboursville, WV
Customer Service Associate

- As an associate in outdoor lawn and garden, worked to maintain and care for plants;
- Assisted customers in design of gardens and selection of plants

Hillcrest Landscaping and Nursery — January 1994 – December 1995
Ona, WV
Plant Sales Associate

- As an associate at a retail plant shop, worked to maintain, care for and sell plants

Training

US Army Corps of Engineers Wetland Delineation Course
Wetland mitigation and restoration
Endangered Species Act
Section 106 of the National Historic Preservation Act
Determining Compliance with Section 404(b)(1) Guidelines